Downhole variations

Downhole variations in various geochemical parameters have been plotted for each hole and are presented in Figures 4.17 to 4.62. The lithology, alteration assemblage and intensity are annotated. For lithology, P = pillow lava, L = massive lava, B = breccia, Q = peperite, and H = HVS. For the alteration assemblage, ab = albite, cl = chlorite, co = carbonate, ep = epidote, fu = fuchsite, py = pyrite, se = sericite, si = silica. fuco = fuchsite + carbonate alteration, absiclfu = albite + silica + chlorite + fuchsite, etc. Intensity ranges from 0 (unaltered) to 5 (most altered).

Unaltered or distal holes are MAC 31, MAC 10, HL 246, and HL 541. Altered or proximal holes are HL 5, HL 20, HL 51, and HL 12. MAC 19 contains fuchsite alteration and is 1500 metres east of the deposit and HL 841 also contains fuchsite alteration and is 900 metres north-east of the deposit. A point summary for each geochemical parameter is shown below:

Major elements

SiO_2	There are no consistent patterns in SiO_2 in unaltered holes. SiO_2 is more erratic near the deposit, reflecting lower values reported in the core lava and increased carbonate. Levels in the HVS are elevated in proximal holes.
TiO_2	TiO_2 shows no pattern except for higher levels in HL 20 directly above the HVS. MAC 10 exhibits the most irregular distribution..
Al_2O_3	Al_2O_3 is also somewhat erratic in MAC 10, and again is elevated in HL 20 in the same positions as TiO_2. There are no overall patterns however.

Fe_2O_3	Fe_2O_3 tends to be depleted for considerable lengths of proximal holes, except where pyrite alteration occurs, where it is elevated. Fe_2O_3 is strongly elevated at the top of proximal hole HL 12. Fe_2O_3 is also consistently depleted in HL 841.
MnO	MnO levels are more erratic in proximal holes than unaltered holes especially near the HVS, with depletion in HL 20 and HL 841. MnO levels in the HVS are somewhat depressed.
MgO	MgO is erratic, with strong depletion over much of the length in proximal holes and HL 841. MgO levels in the HVS are depressed.
CaO	CaO levels are very erratic in proximal holes, mainly being elevated, including HL 841 and the top of MAC 19, but also being strongly depleted in HL 20where pyrite-sericite alteration is dominant. CaO is very depleted within the HVS.
Na_2O	Na_2O levels are quite erratic in proximal holes with strong depletion in HL 20 and HL 5 near the HVS, but elevated levels in HL 12. There is consistent Na_2O depletion in HL 841, and strong depletion at the top of MAC 19.
K_2O	K_2O levels are also somewhat erratic in MAC 10 and elevated towards the base of HL 541, both distal holes. K_2O is elevated towards the base of HL 5, strongly elevated towards the base of HL 20, but slightly depleted towards the base of HL 12, all proximal holes. K_2O is strongly elevated at the top of MAC 19 and elevated for most of HL 841. Levels are higher within the HVS.

BaO	BaO is elevated at the top and middle of MAC 10, and is elevated in parts of all proximal hole, especially near the top of HL 5.
P_2O_5	P_2O_5 levels are depleted towards the base of HL 20, HL 51 and HL 5. P_2O_5 is depleted in the bottom half of HL 841 and at the top of MAC 19, and is very erratic in unaltered hole MAC 10.
S	S levels are erratic but elevated in proximal holes, HL 841 and unaltered hole HL 246. S is elevated within the HVS.
C	C mirrors CaO.

Trace elements

Sc, V	Sc and V display no downhole trends.
Cr.	The "core lava" is delineated by elevated Cr in proximal holes and HL 841.
Cr	is lower in the HVS.
Ni	Ni in elevated in proximal holes only, and is lower in the HVS.
Cu, Zn	These show no discernible patterns.
As	As is elevated in proximal holes, very strongly in HL 20, 51 and 12, with a reasonably consistent downhole increase in HL 20. As is elevated overall in HL 841, and in HL 246.
Rb	Rb levels mirror K_2O.
Sr	Sr displays a similar pattern to Na_2O.
Zr, Nb, Y	Moderate to strong depletion in Zr and Nb, and subtle depletion in Y delineates the "core lava" in proximal holes and HL 841. All tend to be higher in the HVS.

Mo	Mo are much higher in the HVS and at the top of holes MAC 31, MAC 10, HL 20 and HL 12.
Ag	Ag levels are higher in the HVS and also in the basalt at the bottom of HL 20 and HL 12.
Cd	There is no discernible pattern in Cd.
Sb	Sb is strongly and consistently elevated in all proximal holes. It is also elevated in HL 841 and HL 246.
Cs	Cs is somewhat elevated in the proximal holes, especially towards the base, at the top of MAC 19 and in parts of HL 841.
La, Ce, Nd	La, Ce and Nd are all depleted in proximal lavas at the position of the "core lava".
Tl	Tl is strongly elevated towards the bottom of HL 5 and HL 20, and elevated in parts of HL 51 and HL 12 and HL 841, but not in MAC 19. Tl is elevated in the HVS in all proximal samples, and in HL 246.
Pb	Pb is quite erratic in both unaltered an proximal holes, but is generally elevated within the HVS.
Bi	Bi appears to be depleted in proximal holes and in HL 841. Bi is a little elevated in the HVS in HL 12, HL 841 and MAC 19.
Th, U	Th and U are both strongly elevated, with a few low spikes in MAC 10, and depleted in the proximal holes and HL 841, delineating the "core lava". Th is a little depleted in MAC 19, except near the top of the hole. Both tend to be higher in the HVS.

Other parameters (Figures 39-42,68-70)

The downhole variation in Ti/Zr clearly delineates the "core lava" from the surrounding lava (see chemostratigraphy section). The Ishikawa alteration index is erratic and only picks out the strong pyrite-sericite alteration in HL 20, whereas the Hellyer alteration index shows elevated levels in all proximal holes, HL 841, and the top of MAC 19. The Ba/Sr ratio displays an erratic trend. PIMA FeOH and MgOH display no obvious pattern, with MgOH being more erratic than FeOH. Both are slightly elevated in the HVS in proximal holes. The CCP index shows no downhole trends, but is slightly depressed in the HVS.

Variations in downhole chemistry versus alteration type

There is some evidence for whole rock chemistry reflecting visually logged alteration for some elements in some holes, but not for others.

- CaO (Figure 23) shows a good correlation in HL 12 and HL 20
- MnO (Figure 21) shows no downhole correlation with carbonate alteration despite showing a correlation with C in Figure 4.16.
- K_2O (Figure 4.25) shows a good correlation with fuchsite near the bottom of HL 5; near the top of MAC 19; and a good correlation with sericite alteration near the bottom of HL 20 and HL 12; and near the bottom of HL 541.
- MgO (Figure 22) shows a few correlations with chlorite alteration in HL 12 and HL 51
- Fe_2O_3 (Figure 20) increases at the bottom of HL 20 with pyrite-sericite alteration.
- SiO_2 (Figure 4.17) displays an increase with silica alteration in HL 20, MAC 19, and MAC 10.

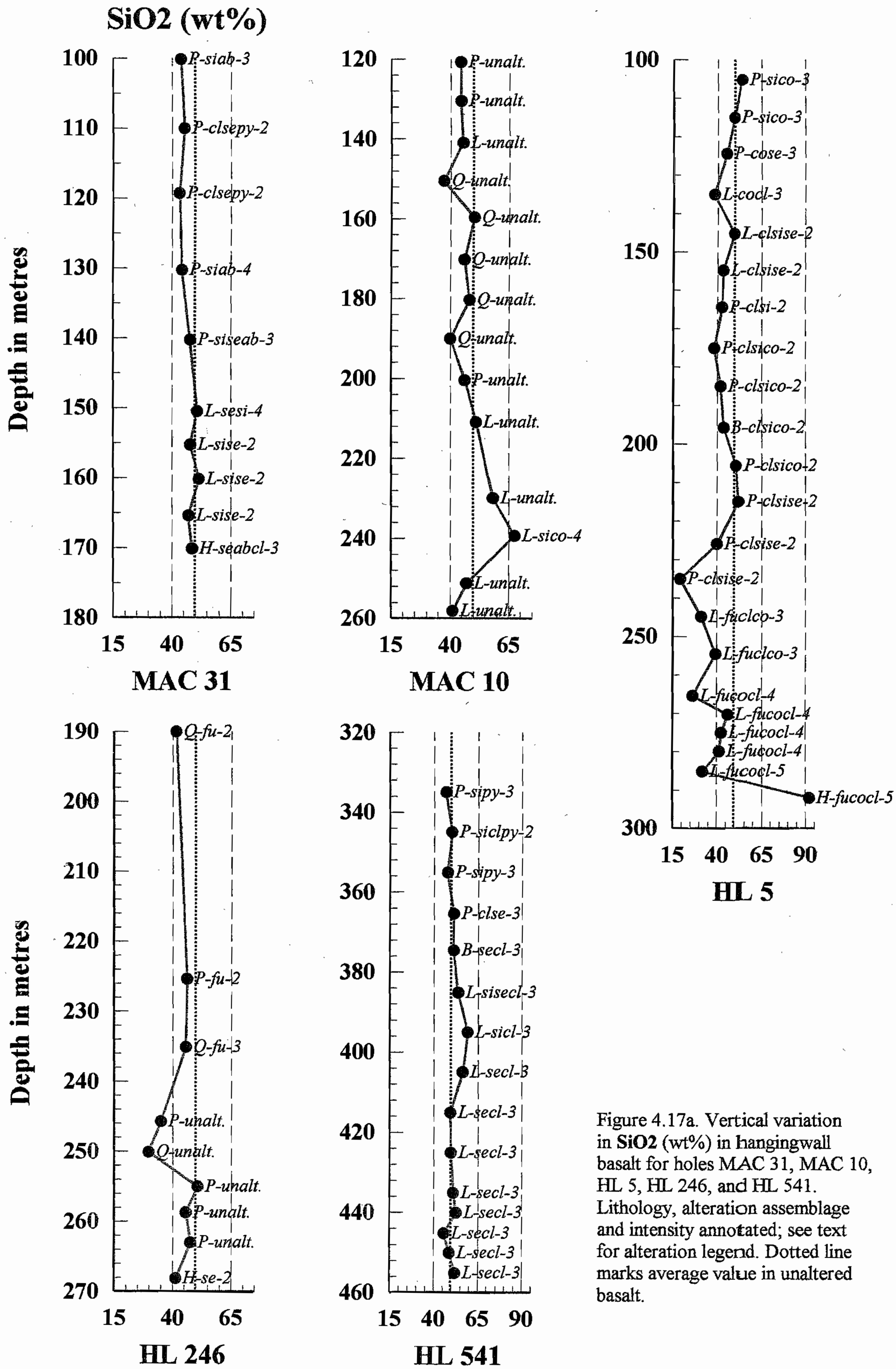


Figure 4.17a. Vertical variation in **SiO2** (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

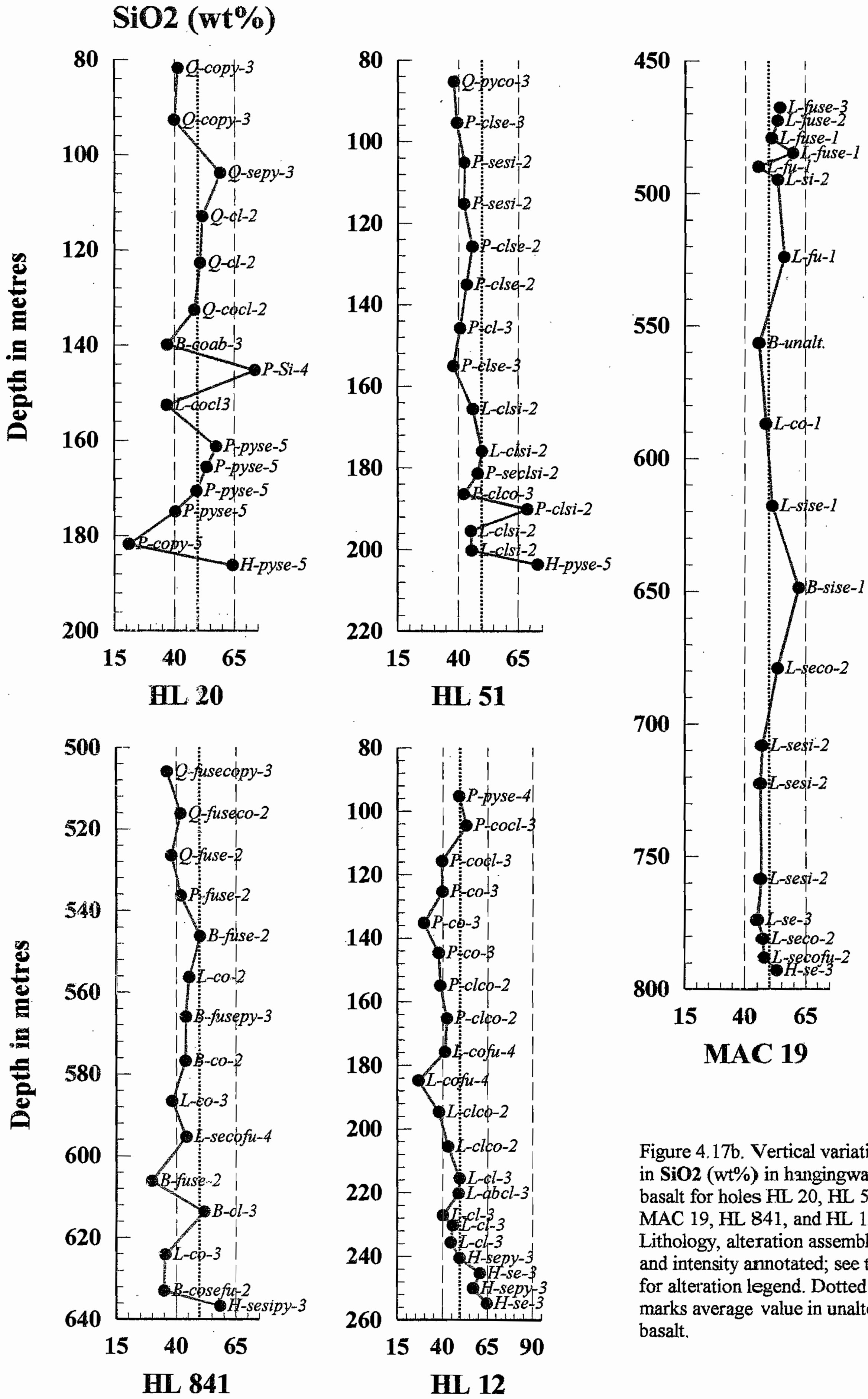


Figure 4.17b. Vertical variation in SiO2 (wt%) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

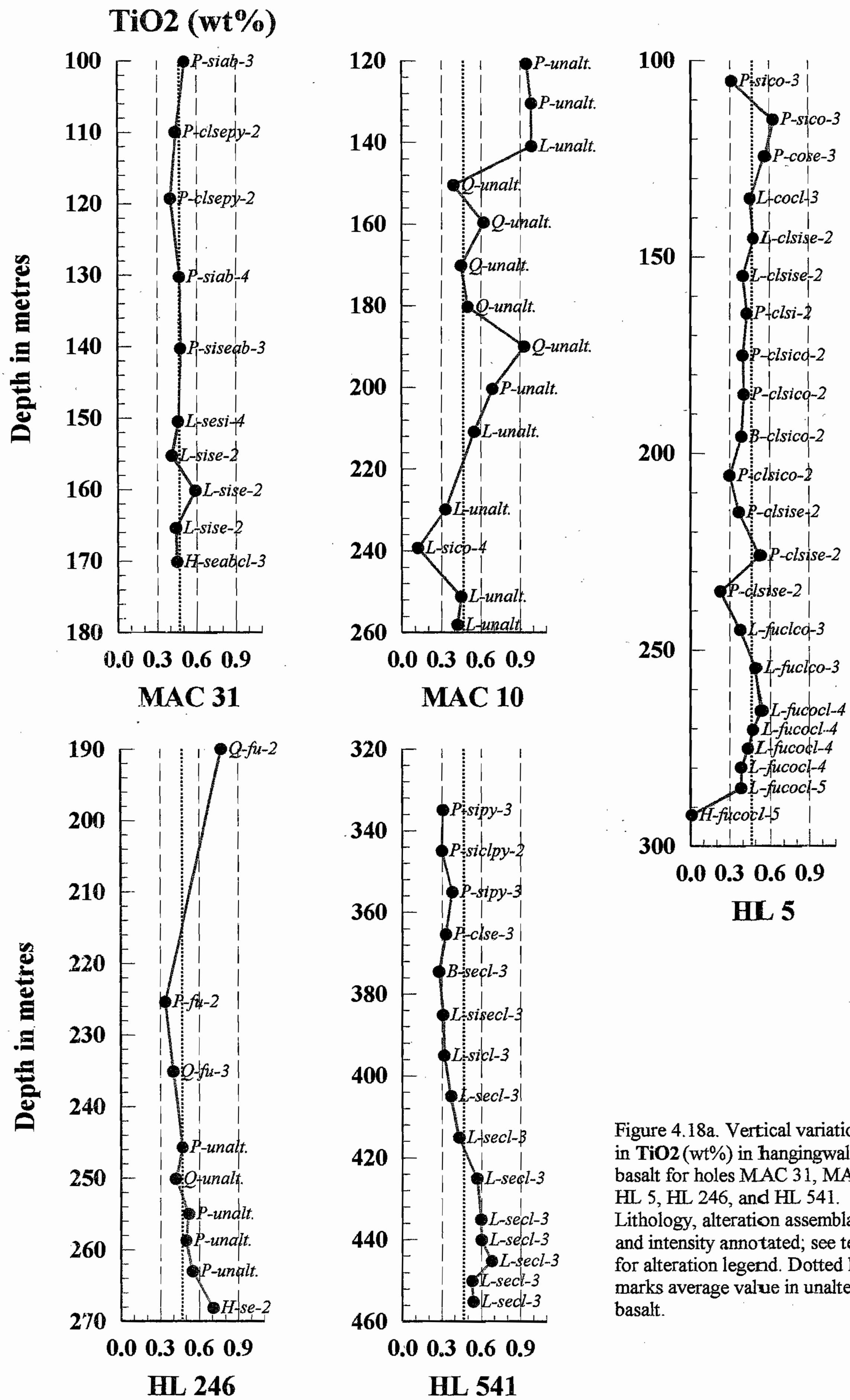


Figure 4.18a. Vertical variation in TiO2 (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

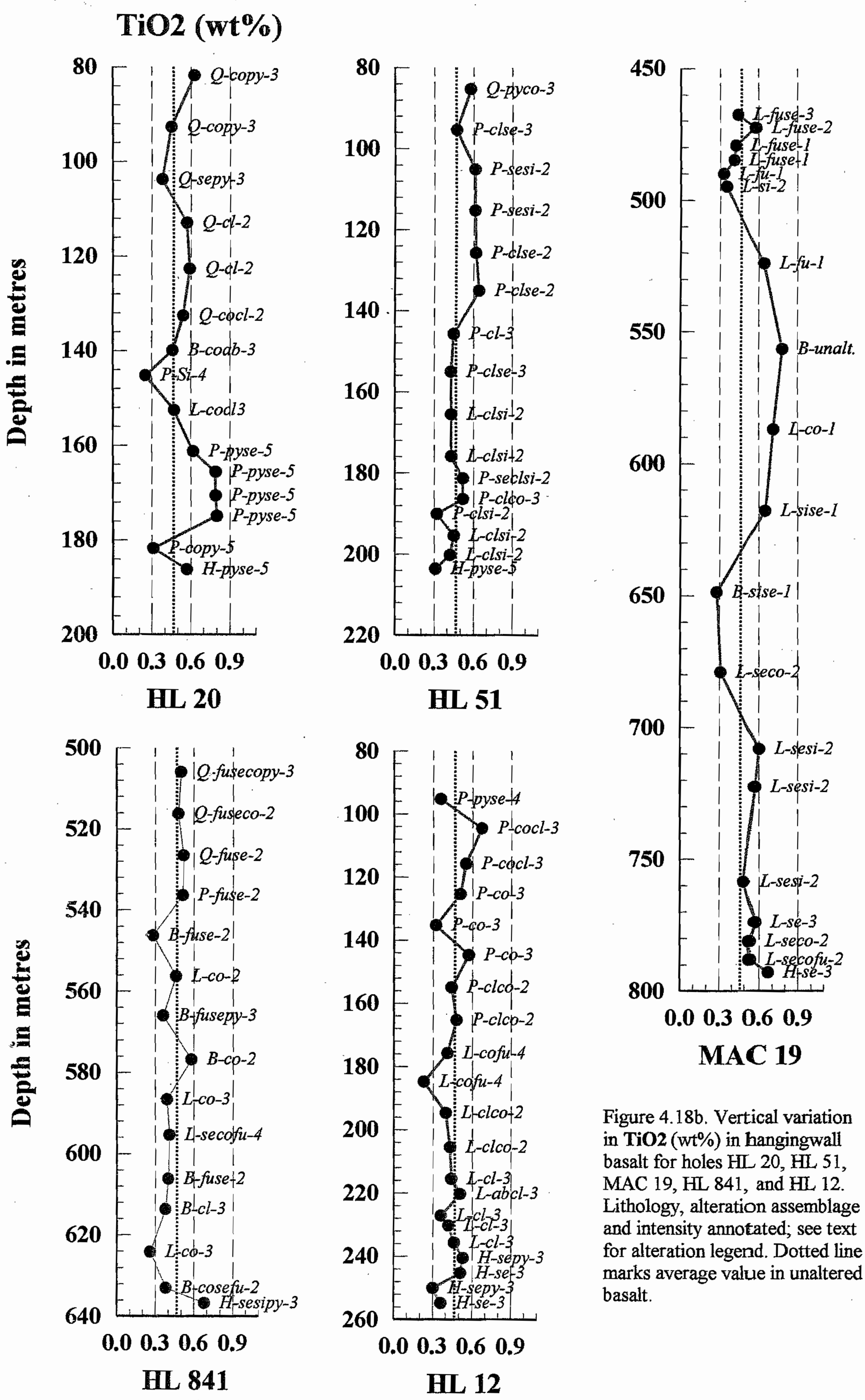
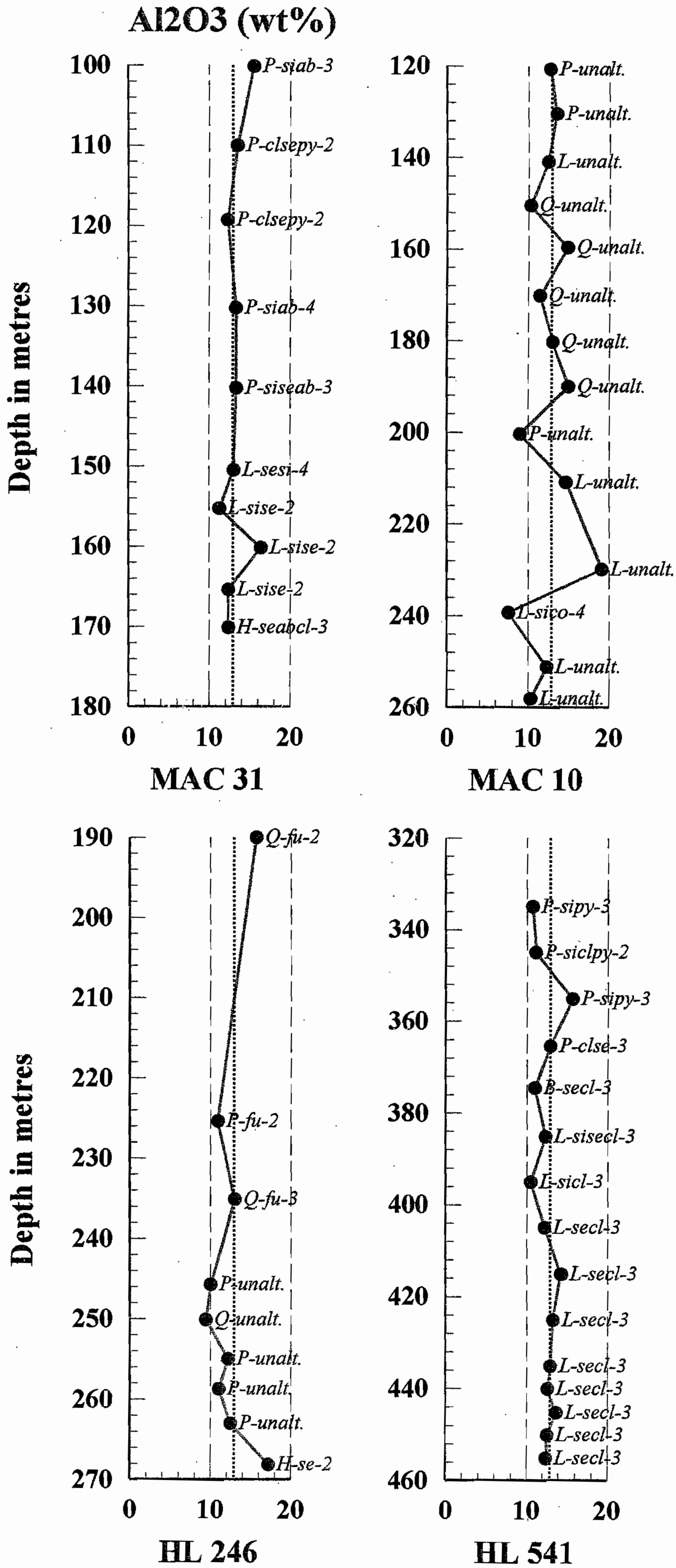


Figure 4.18b. Vertical variation in TiO2 (wt%) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.



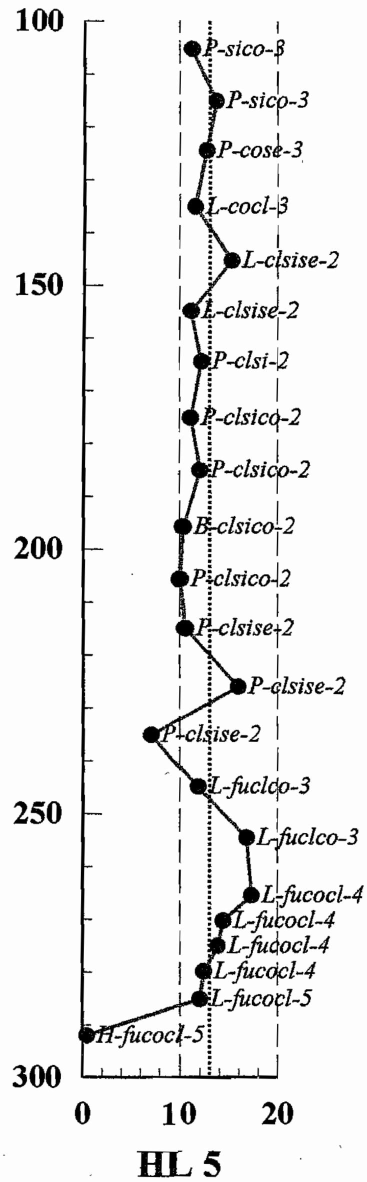


Figure 4.19a. Vertical variation in Al2O3 (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

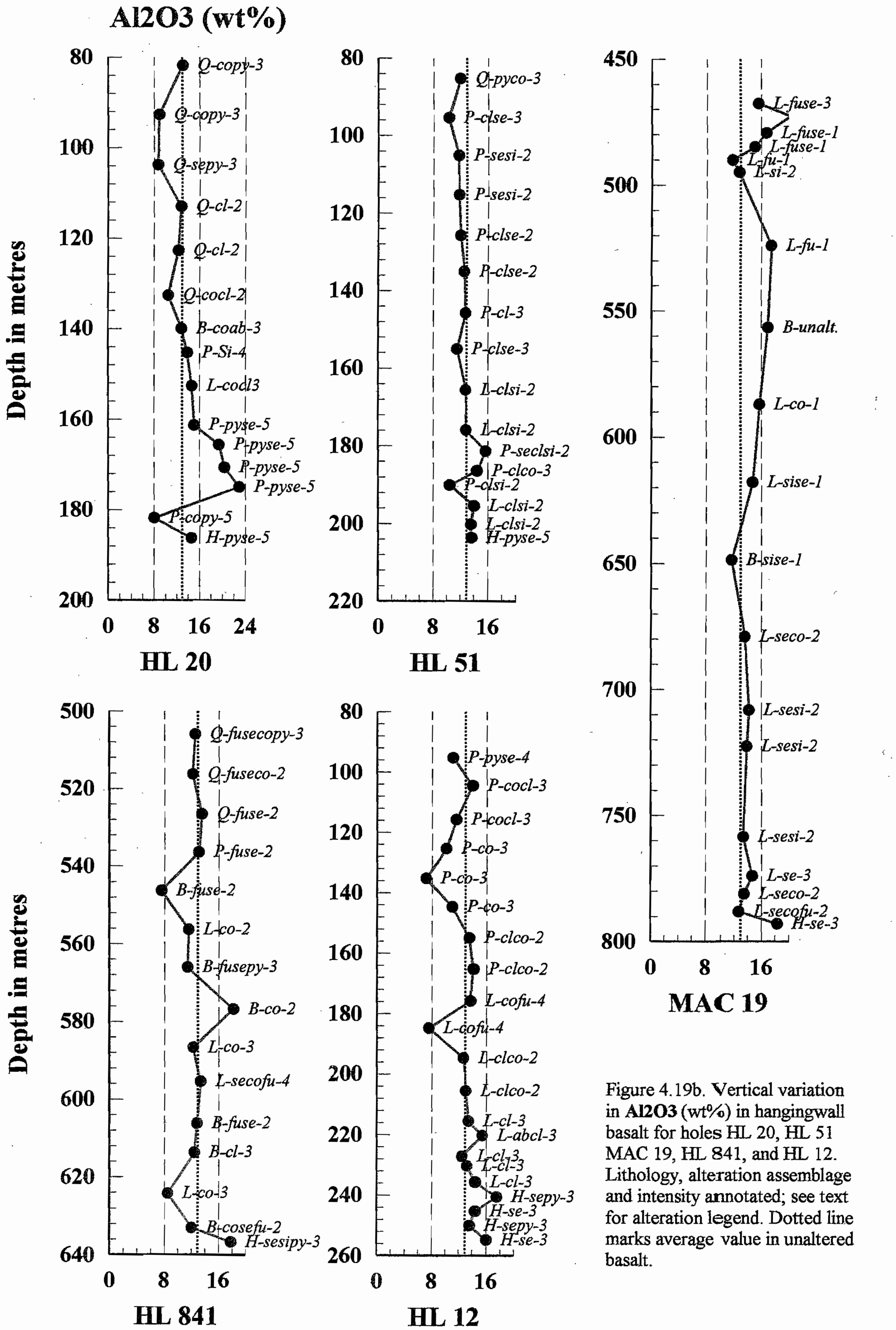


Figure 4.19b. Vertical variation in **Al2O3** (wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

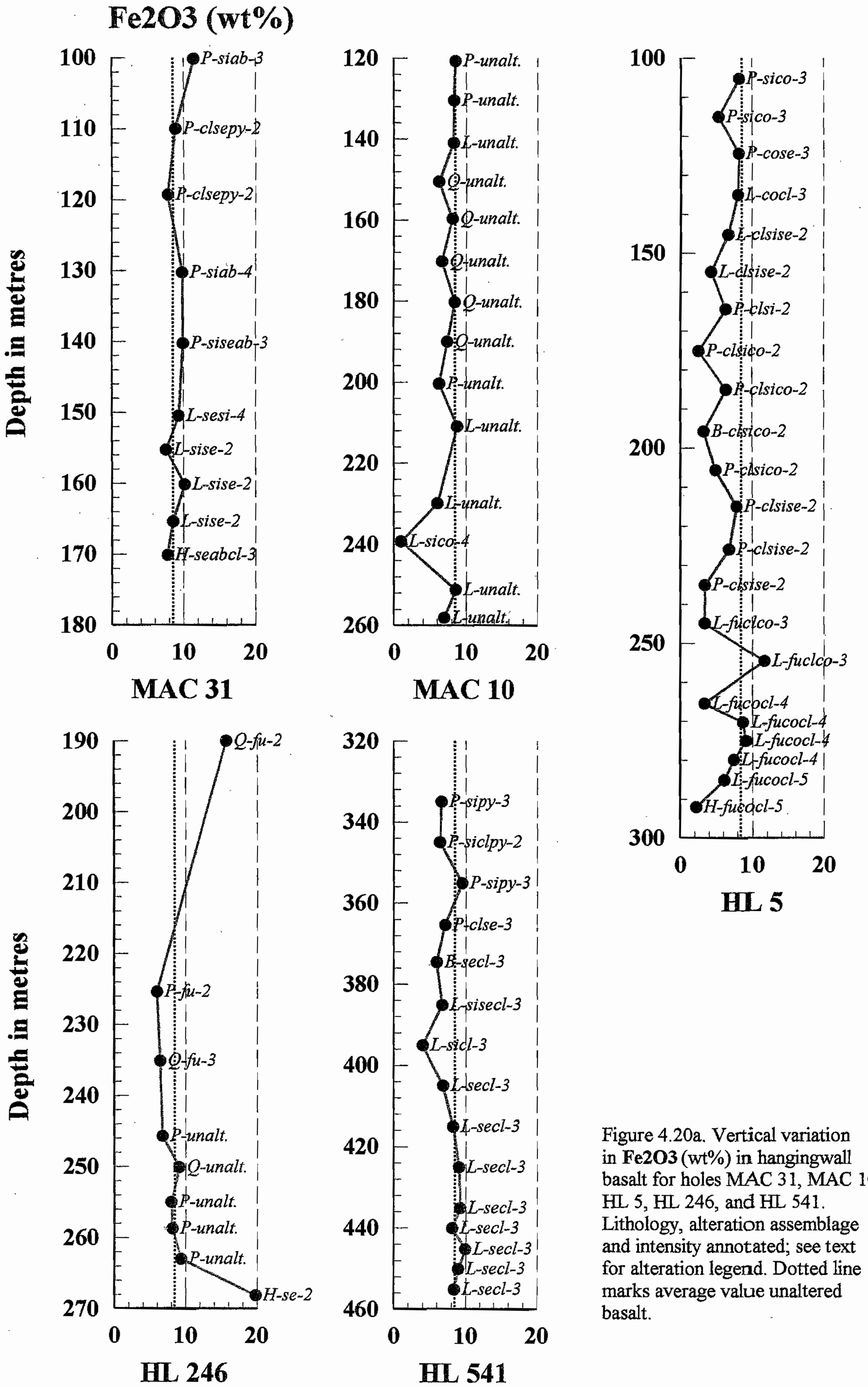


Figure 4.20a. Vertical variation in **Fe2O3** (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value unaltered basalt.

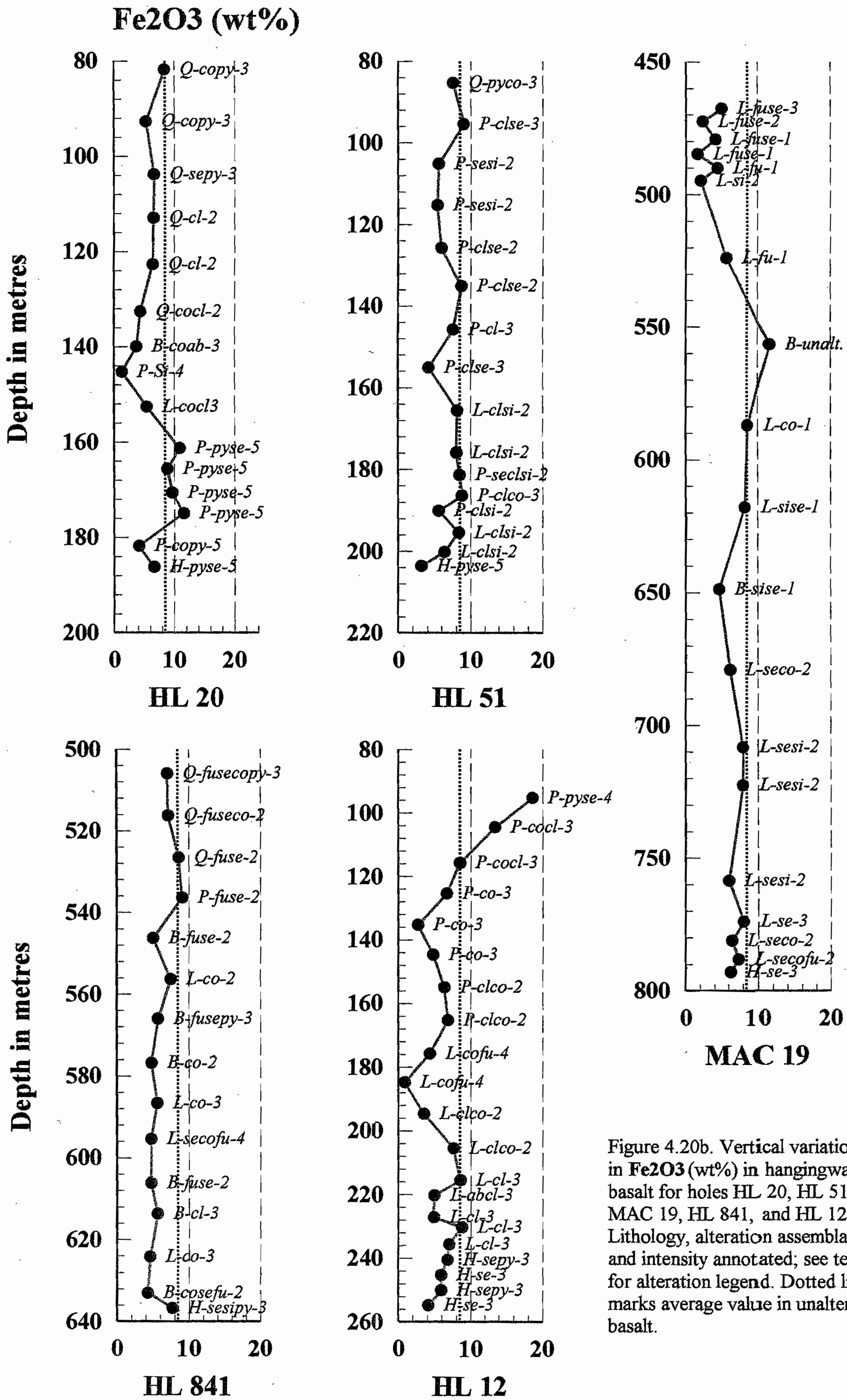


Figure 4.20b. Vertical variation in **Fe2O3** (wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

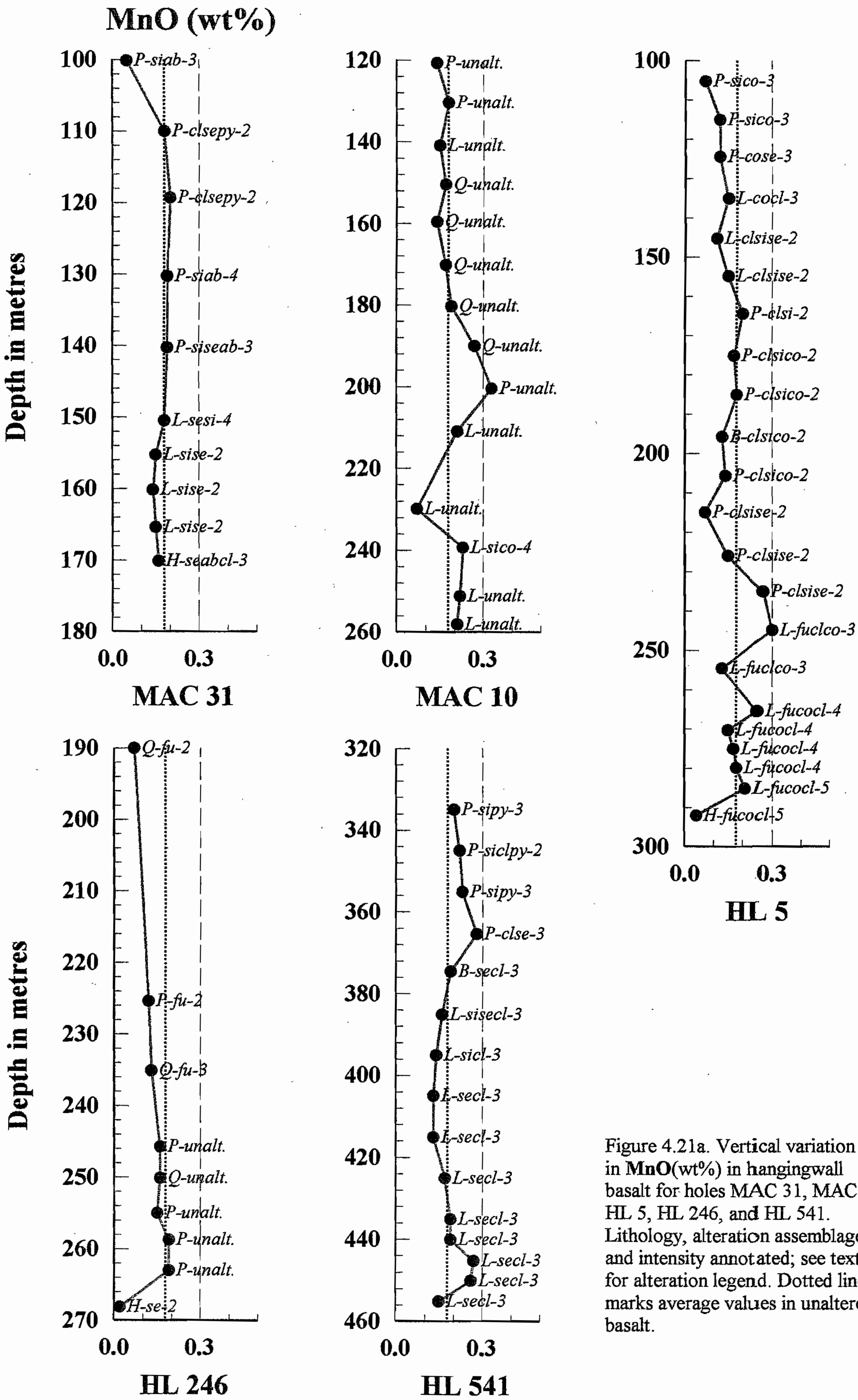


Figure 4.21a. Vertical variation in **MnO**(wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average values in unaltered basalt.

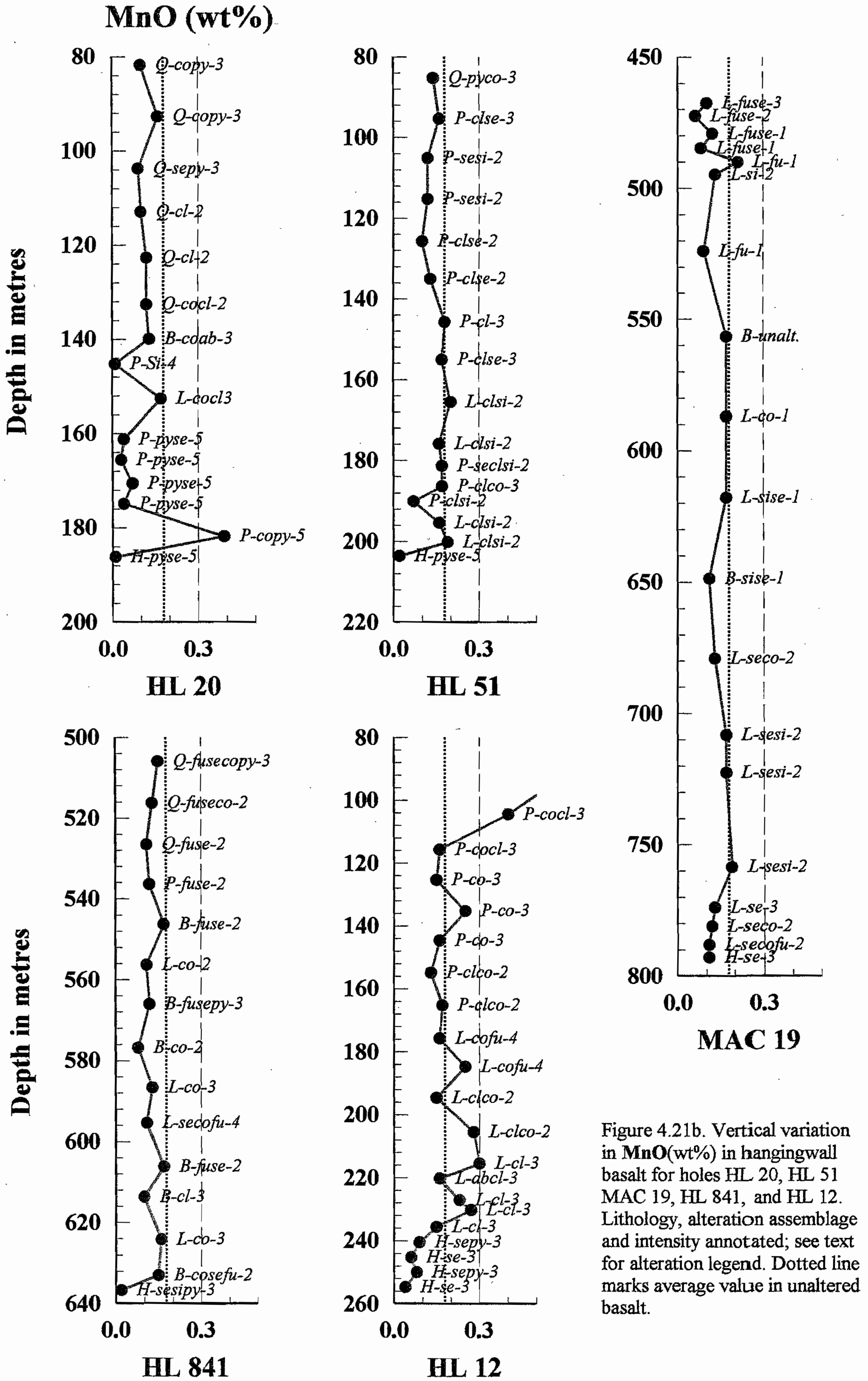


Figure 4.21b. Vertical variation in **MnO**(wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

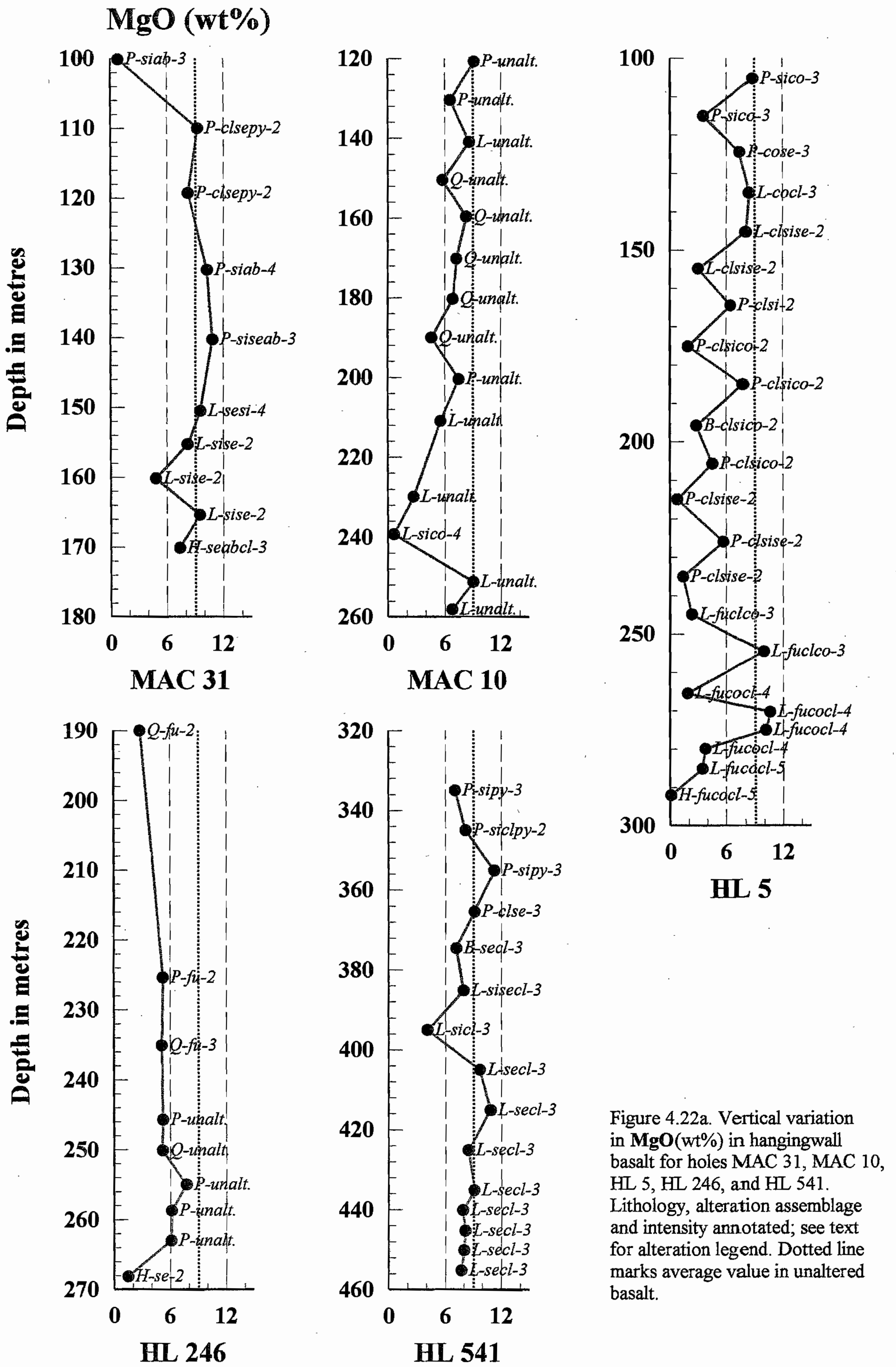


Figure 4.22a. Vertical variation in **MgO**(wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

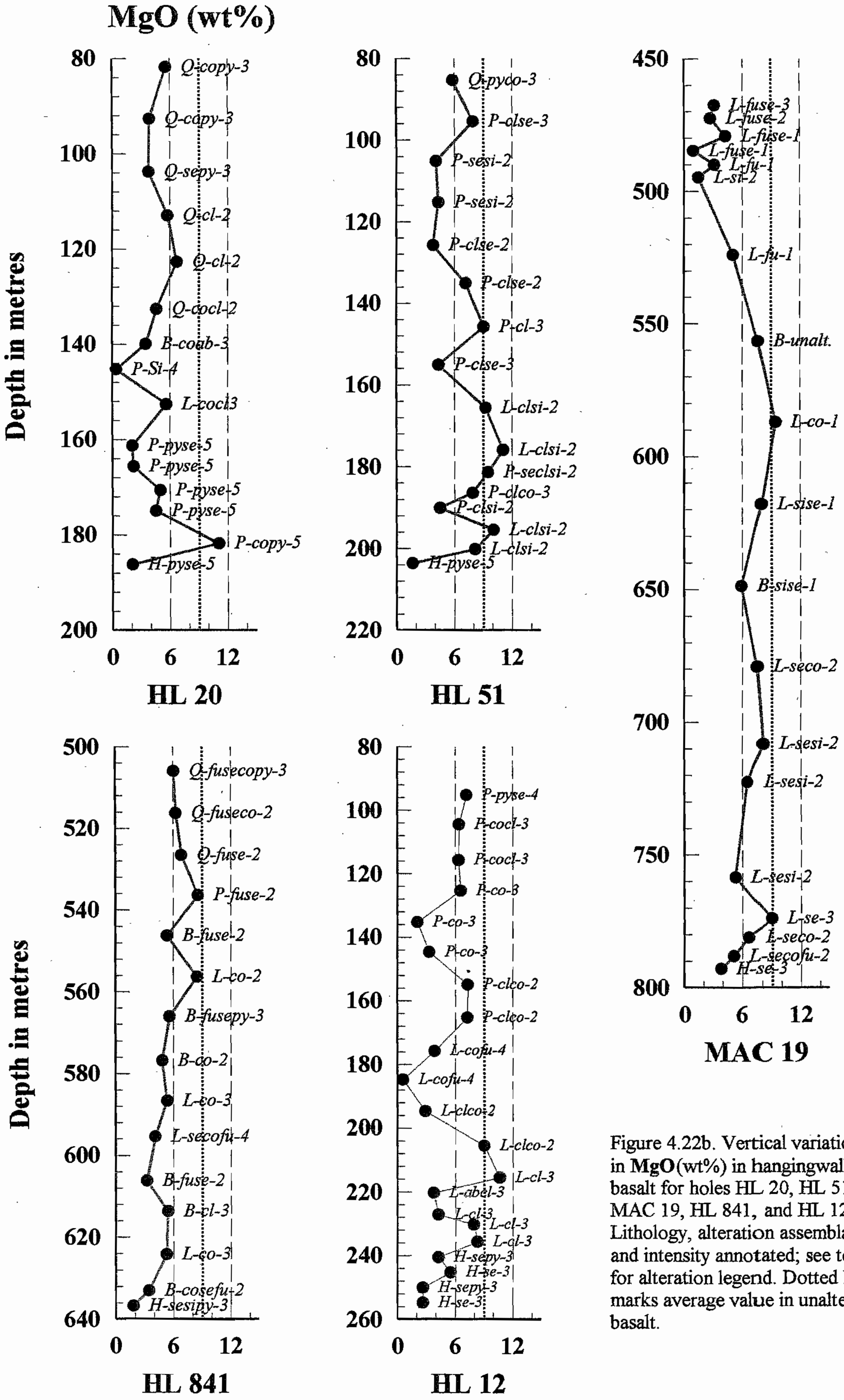


Figure 4.22b. Vertical variation in **MgO**(wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

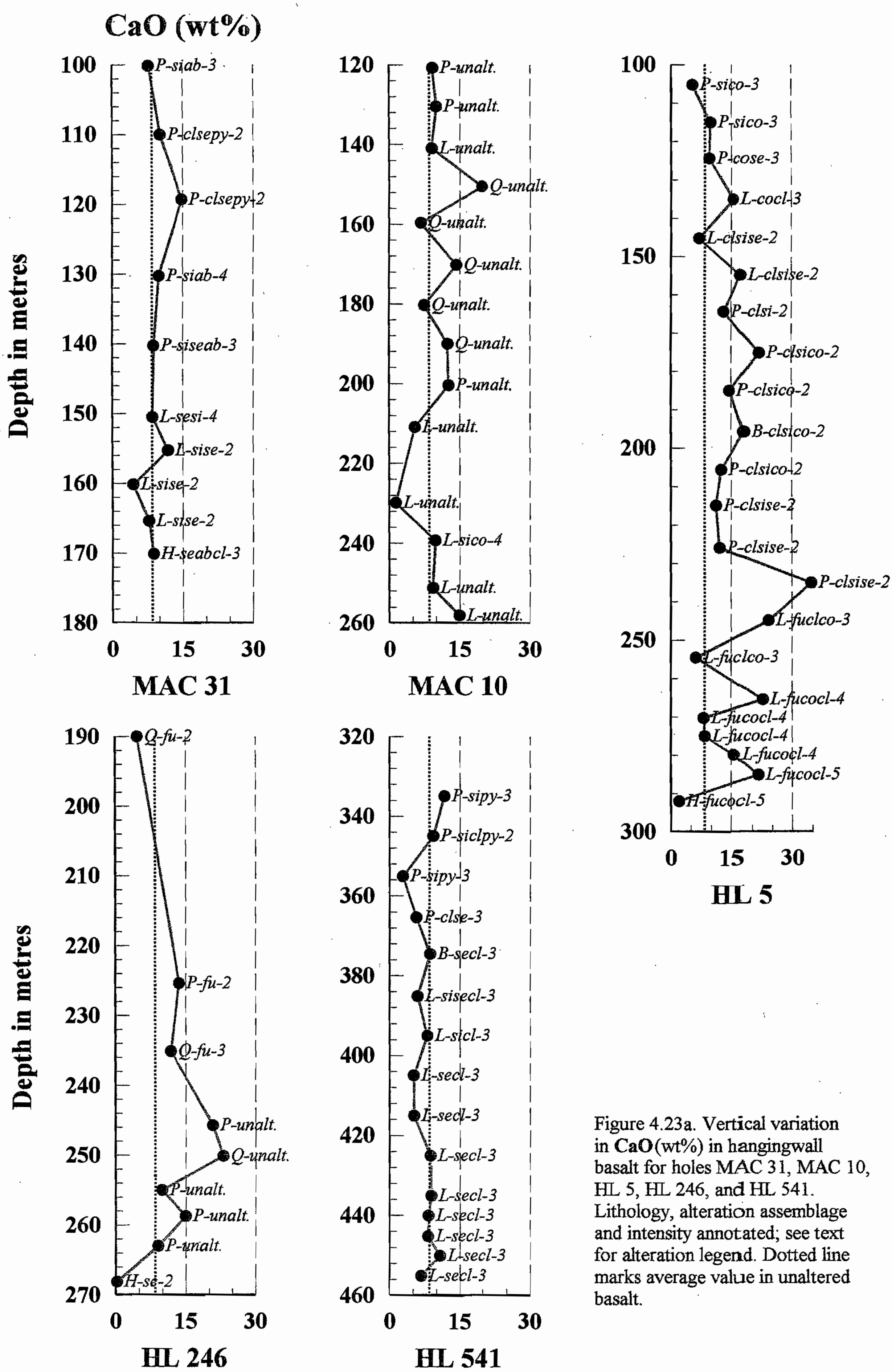


Figure 4.23a. Vertical variation in CaO(wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

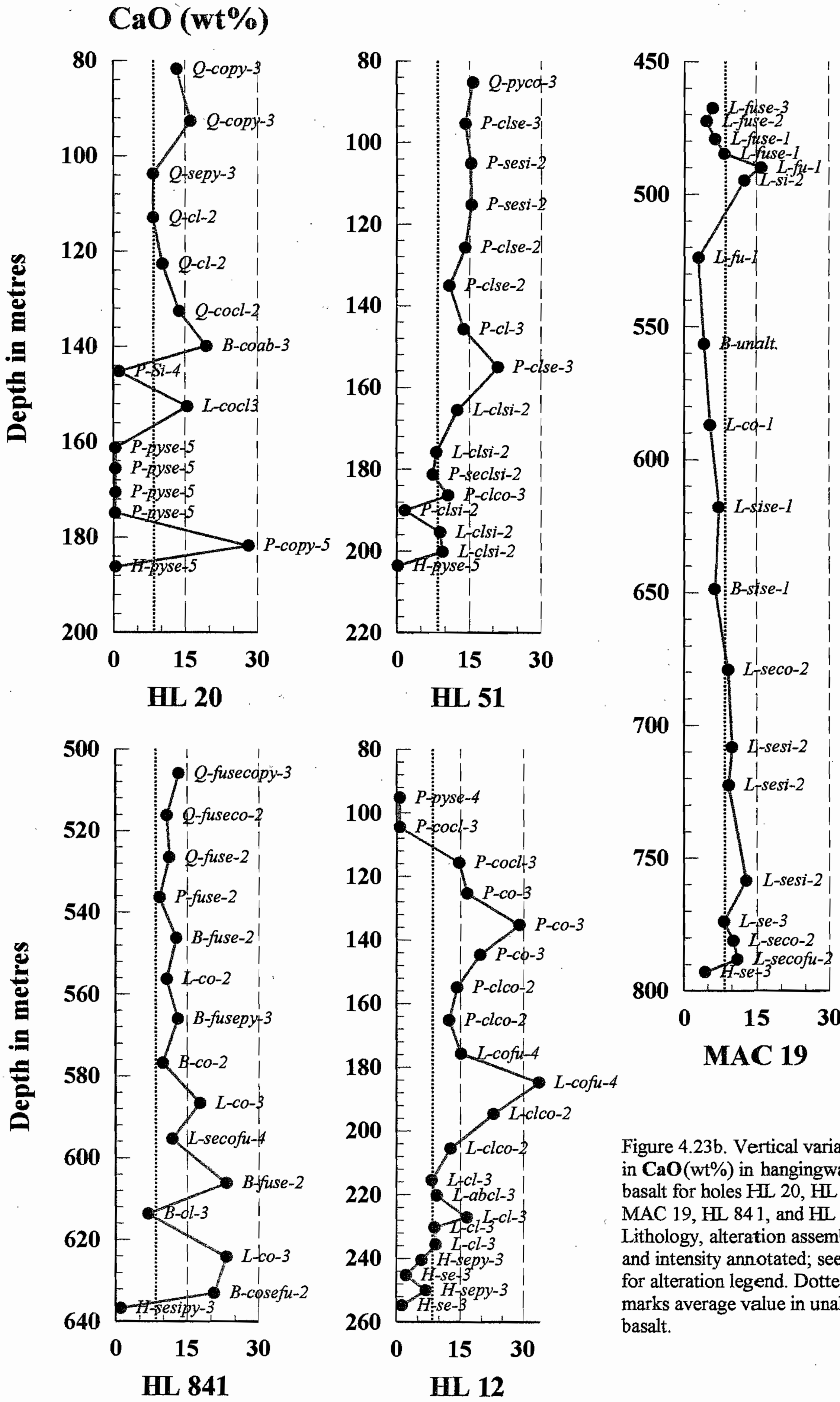


Figure 4.23b. Vertical variation in **CaO**(wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

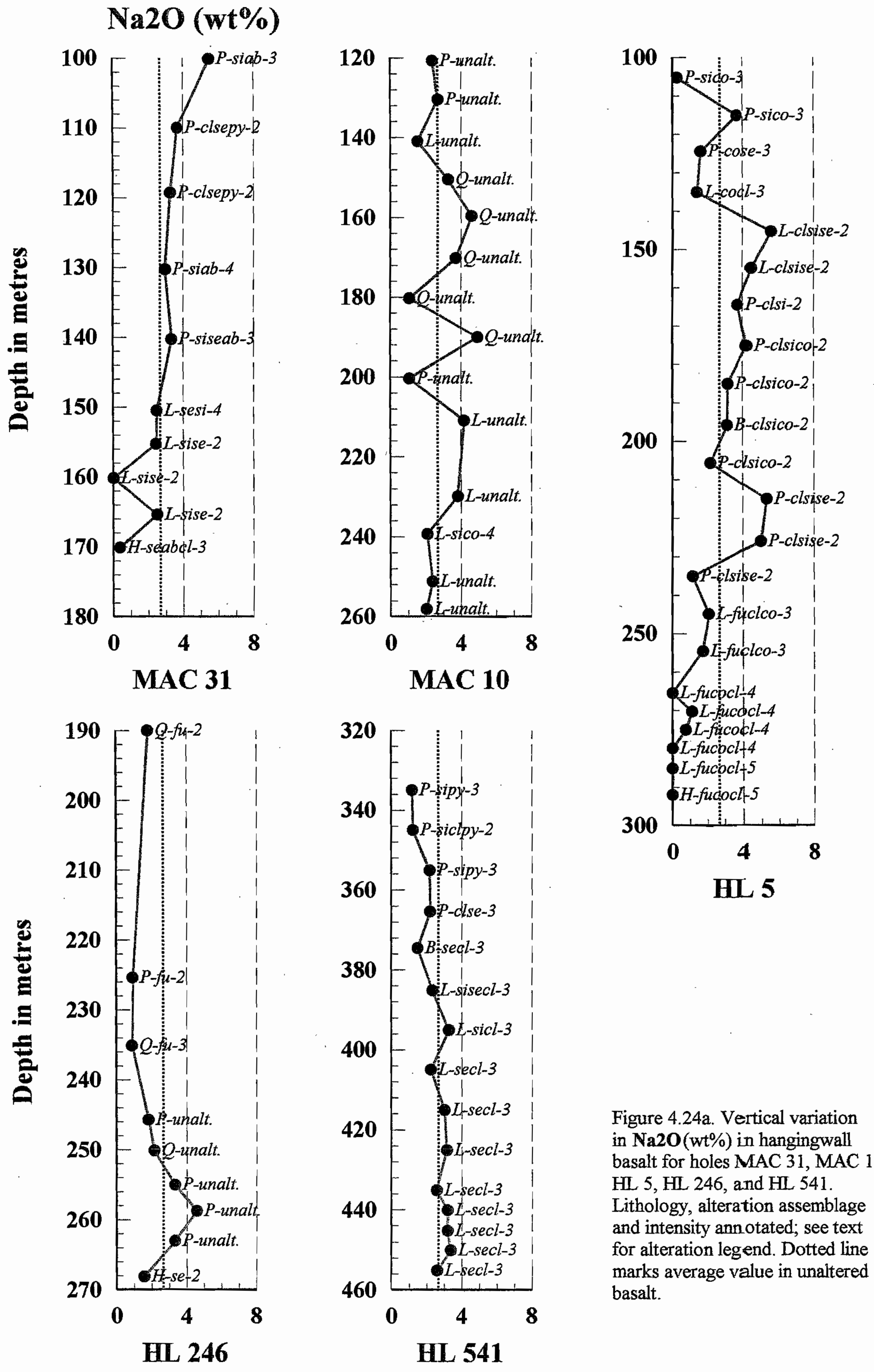


Figure 4.24a. Vertical variation in Na2O (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

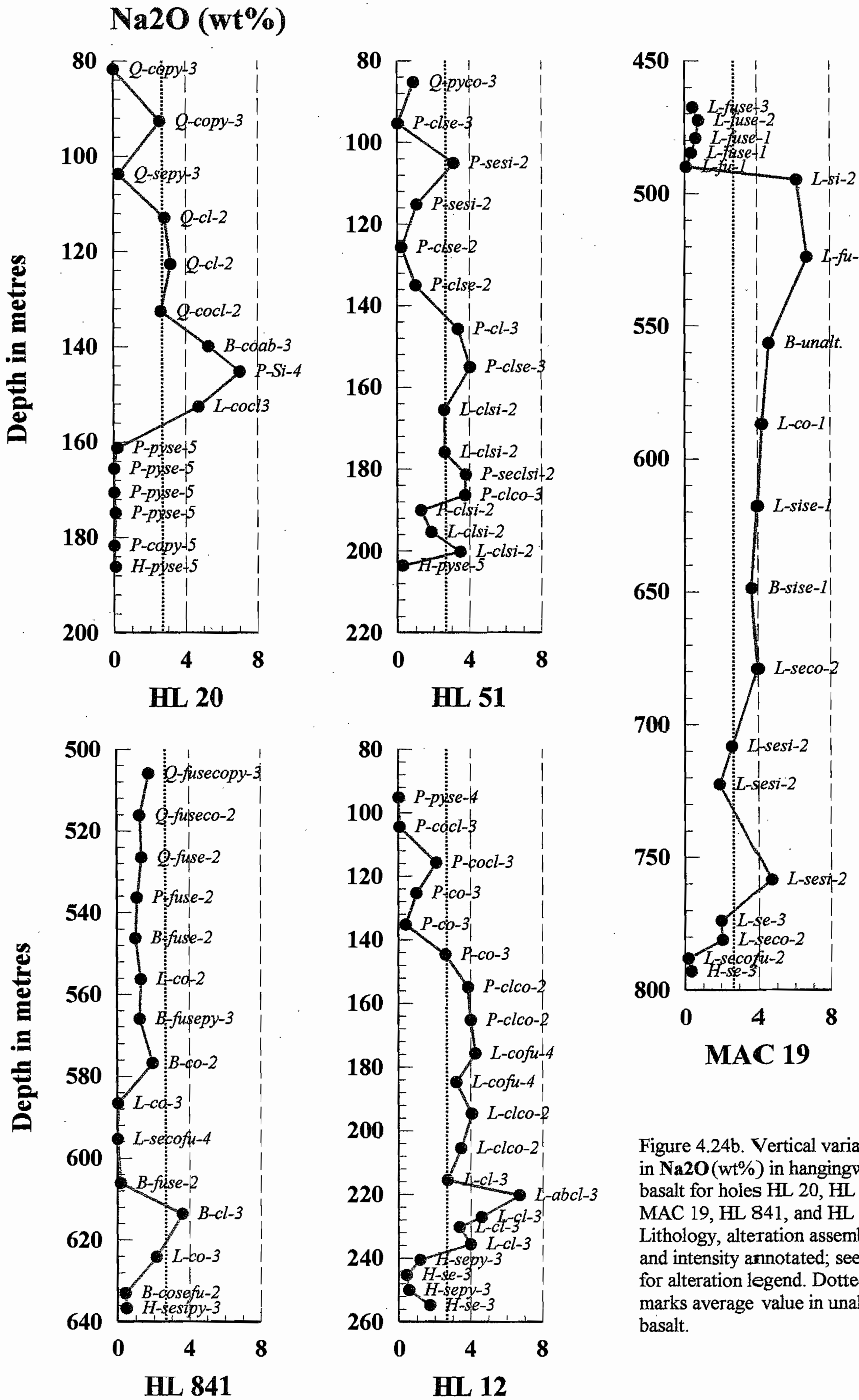


Figure 4.24b. Vertical variation in **Na2O** (wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

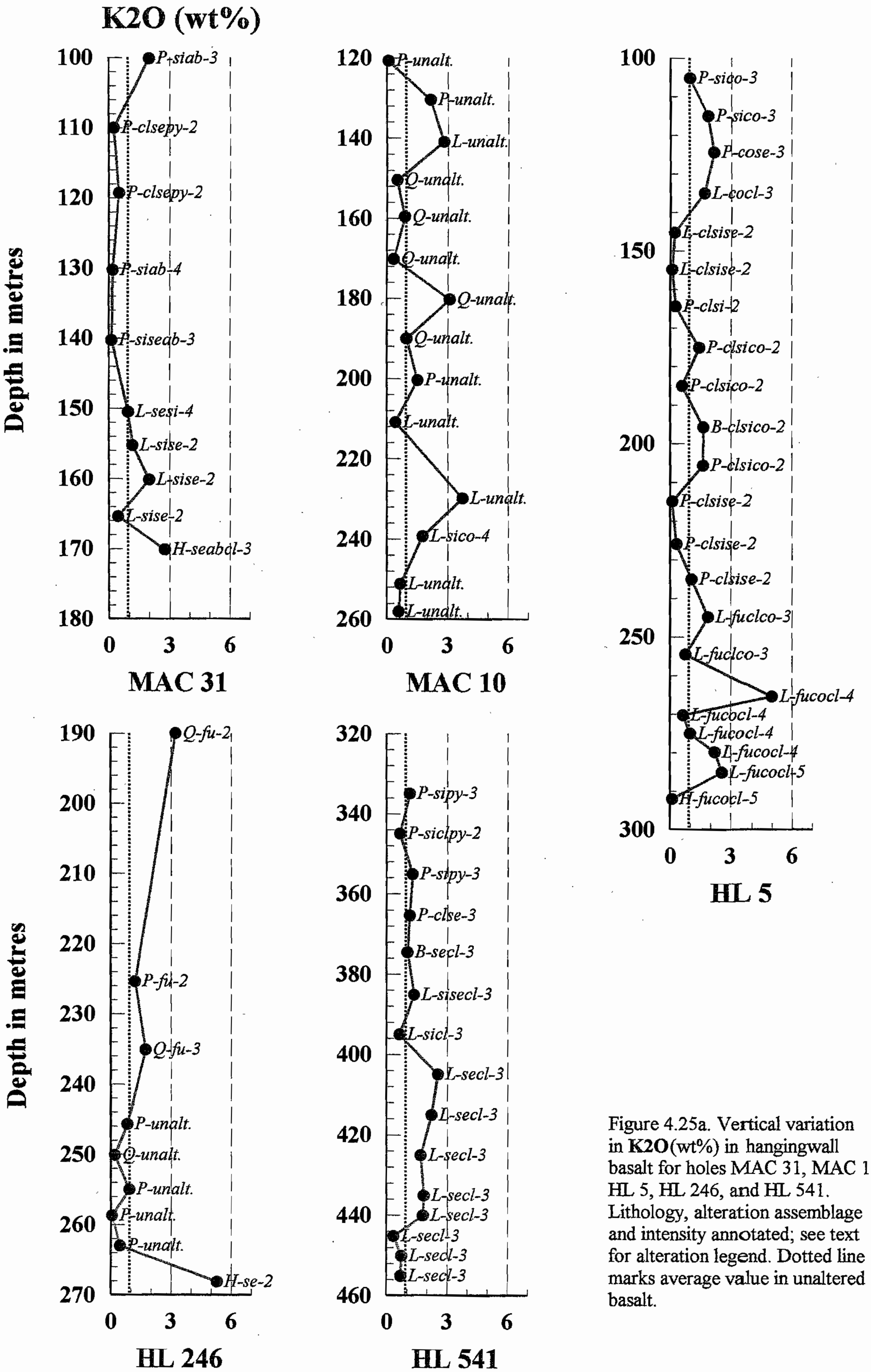


Figure 4.25a. Vertical variation in **K2O**(wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

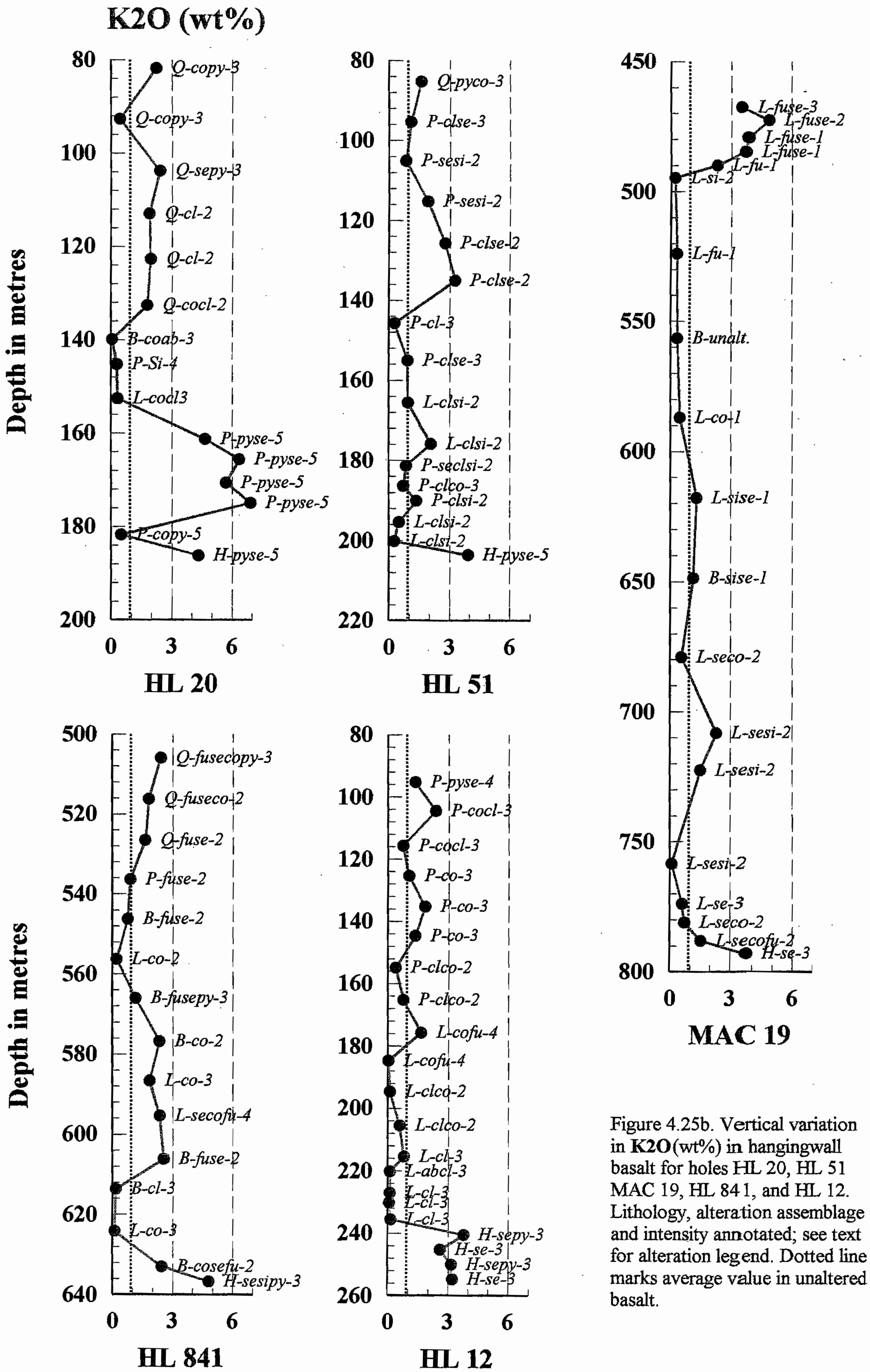


Figure 4.25b. Vertical variation in K2O(wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

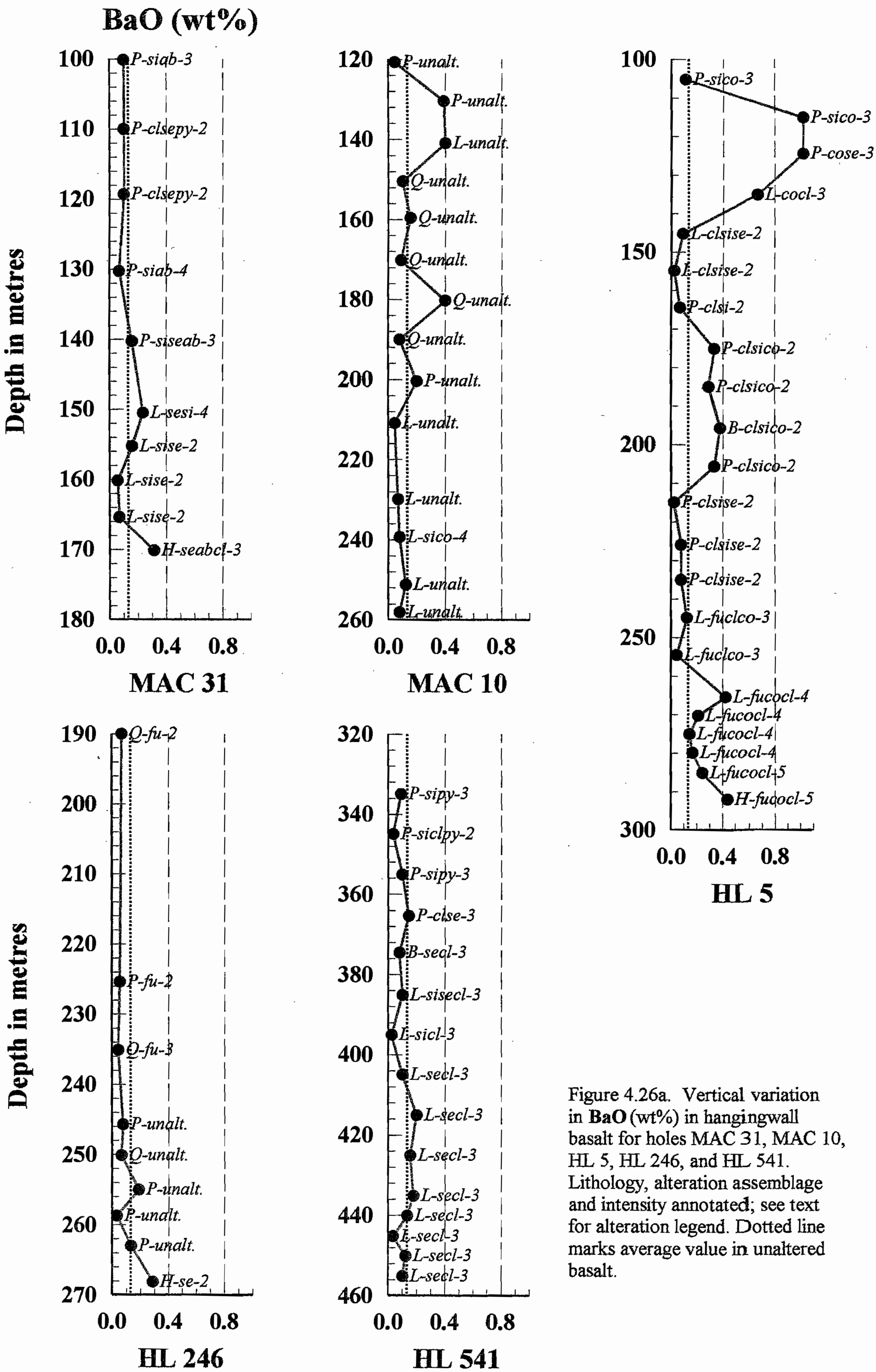


Figure 4.26a. Vertical variation in **BaO** (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

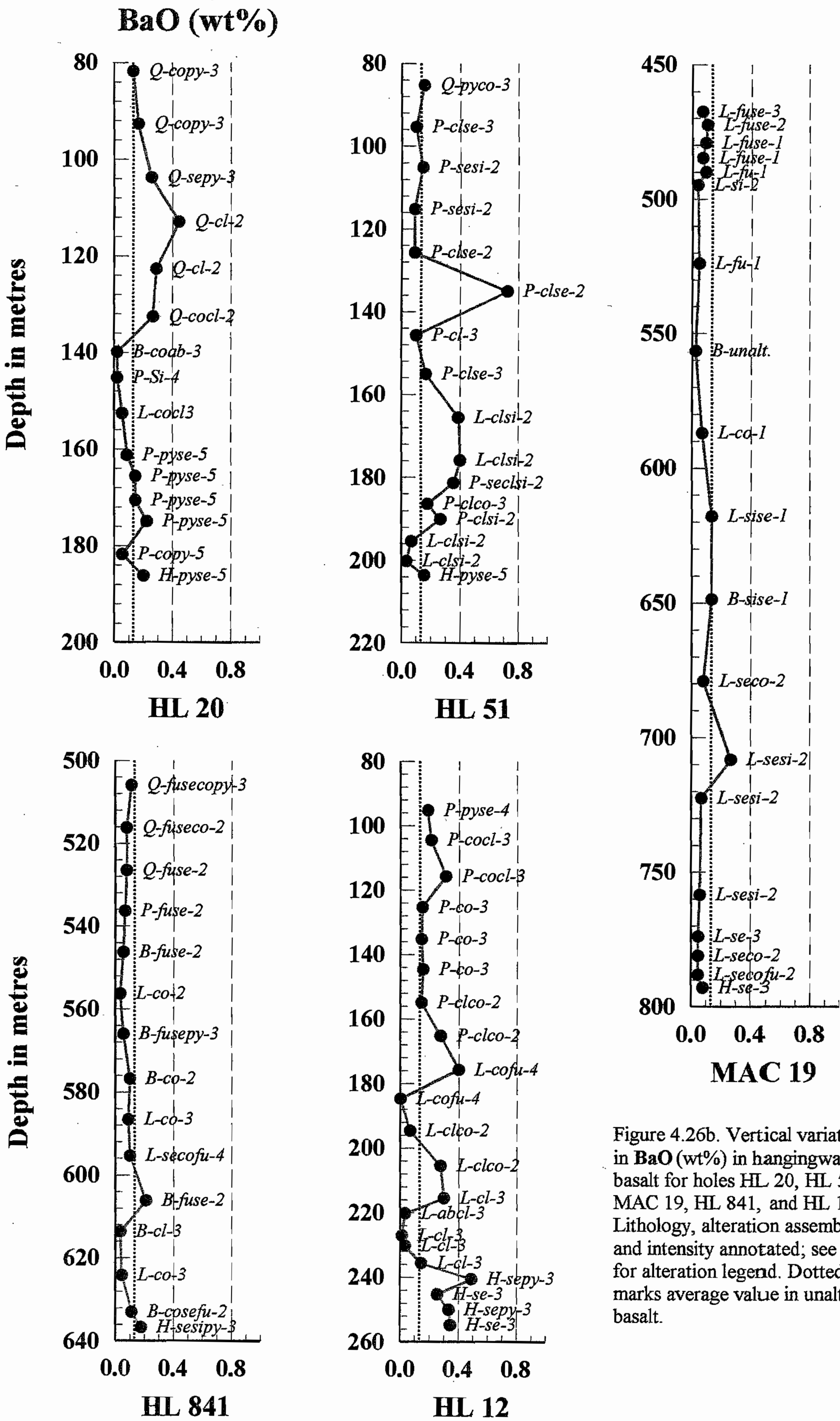


Figure 4.26b. Vertical variation in **BaO** (wt%) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

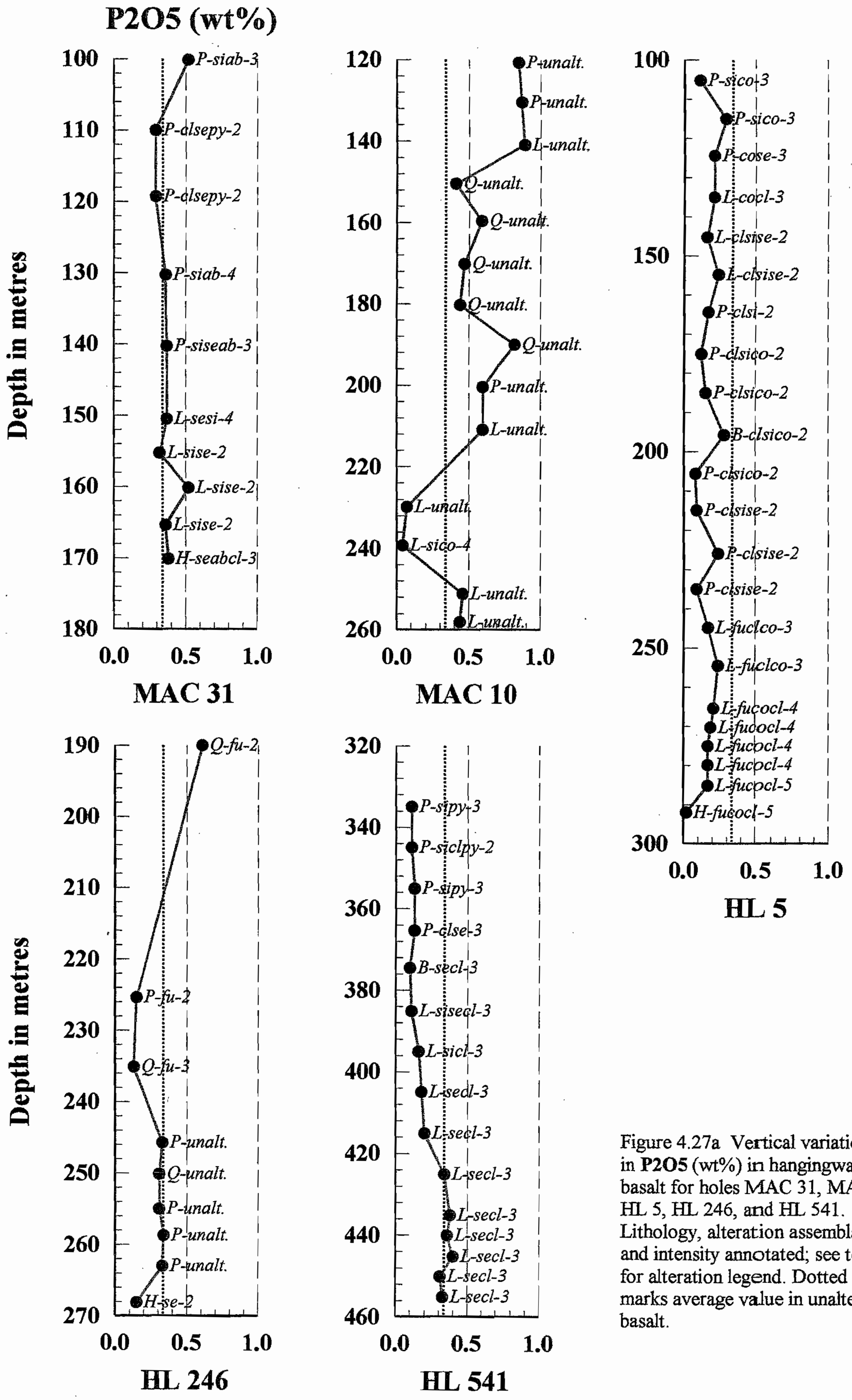


Figure 4.27a Vertical variation in **P2O5** (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

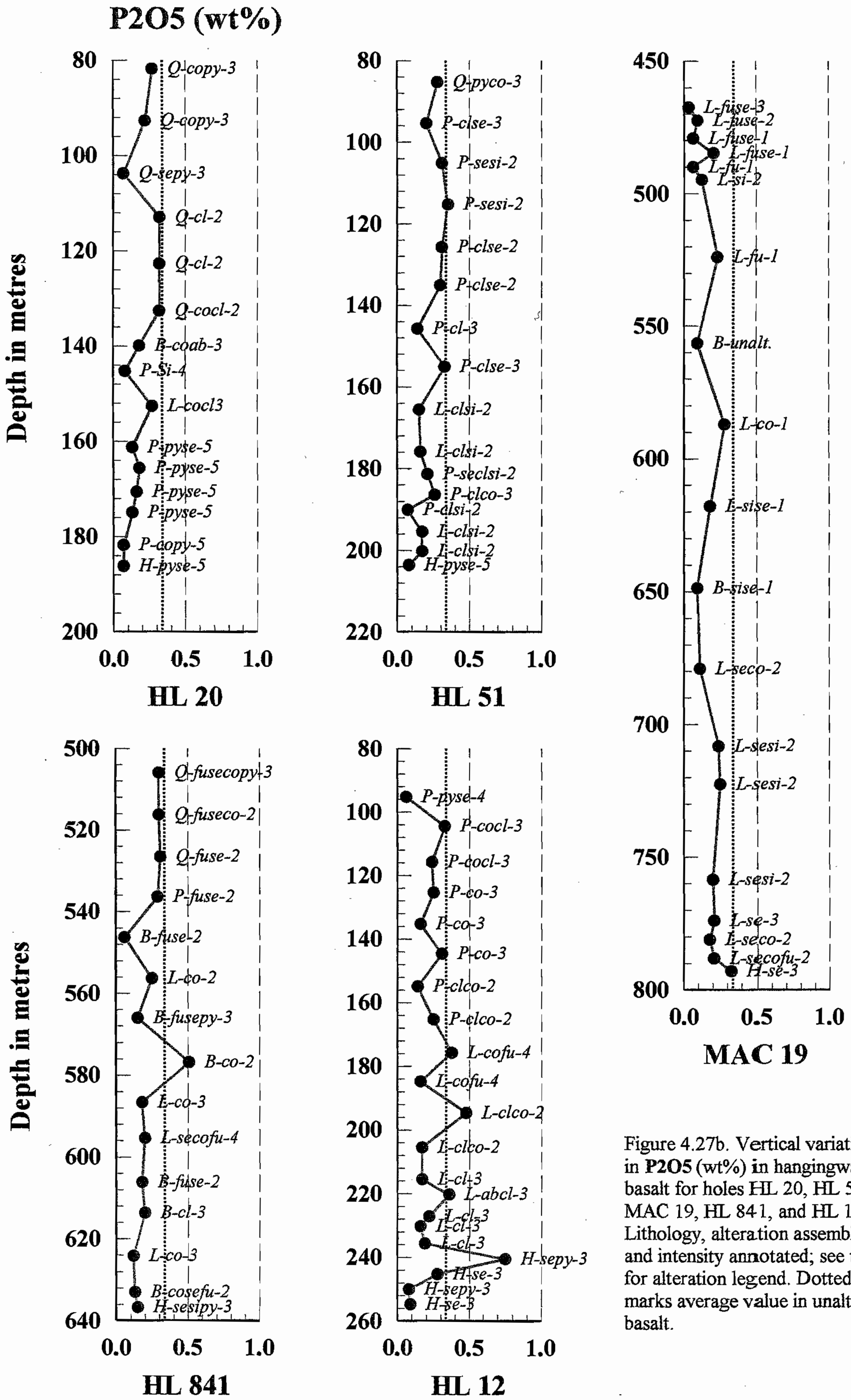


Figure 4.27b. Vertical variation in P2O5 (wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

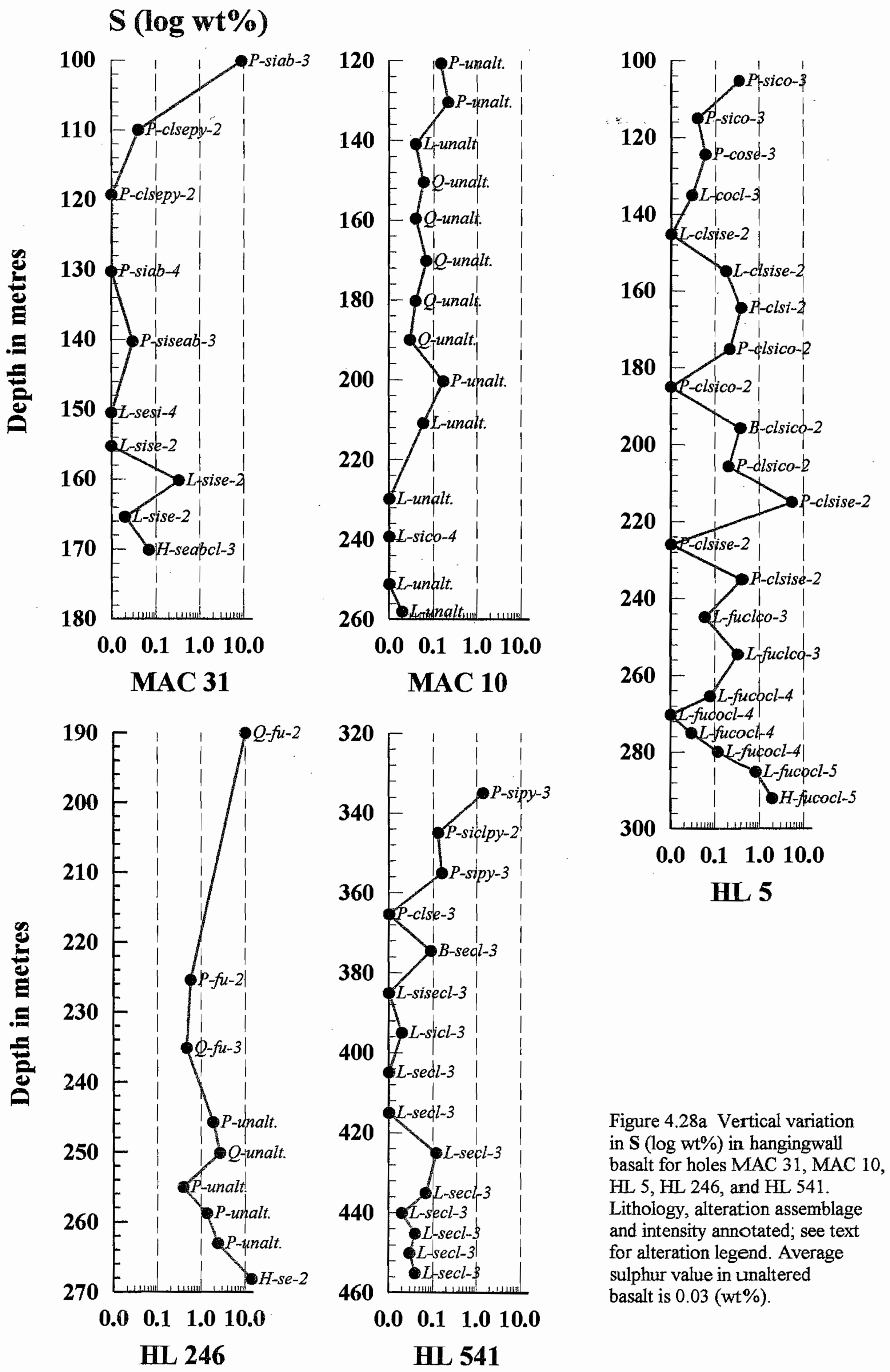


Figure 4.28a Vertical variation in S (log wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Average sulphur value in unaltered basalt is 0.03 (wt%).

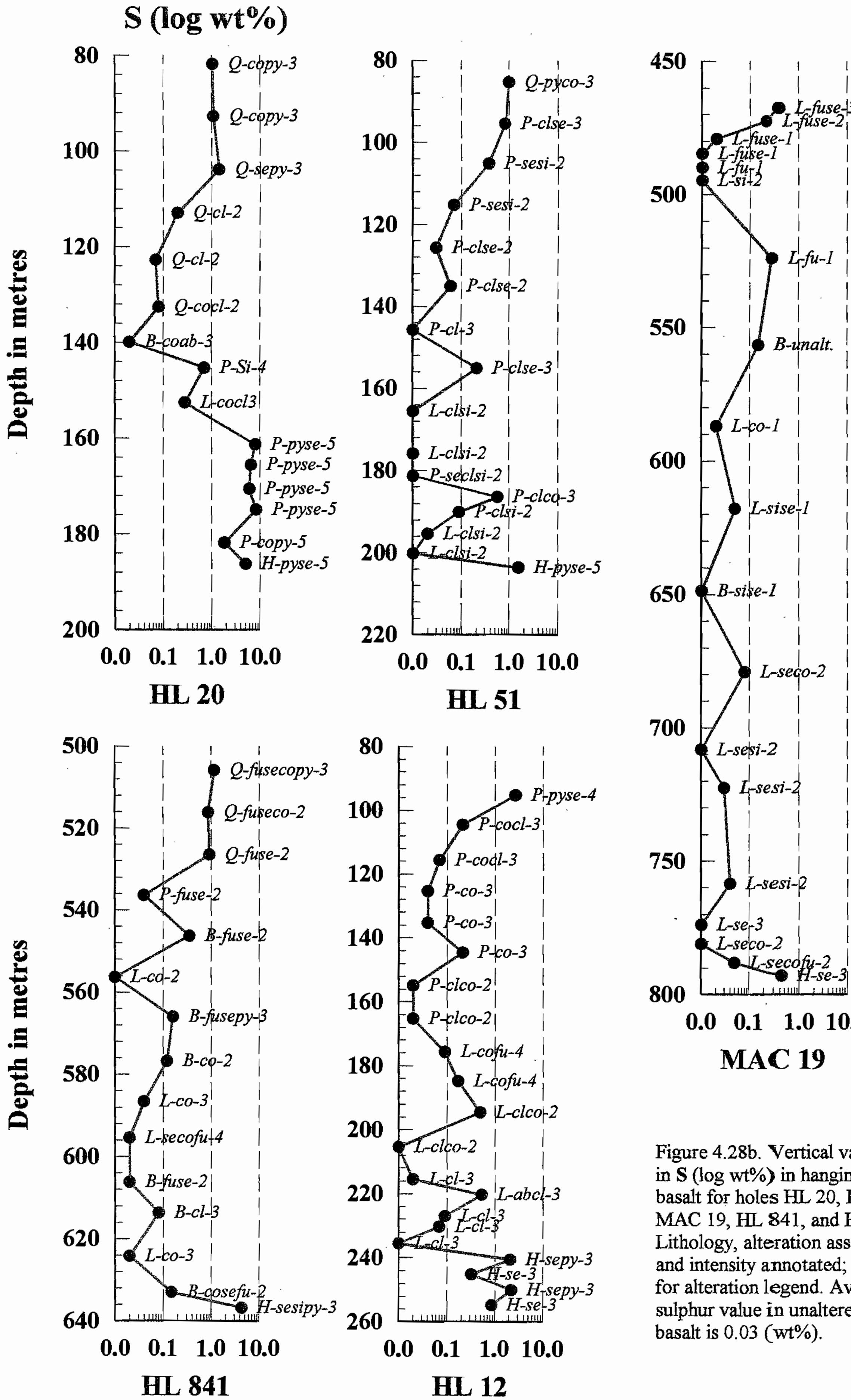


Figure 4.28b. Vertical variation in S (log wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Average sulphur value in unaltered basalt is 0.03 (wt%).

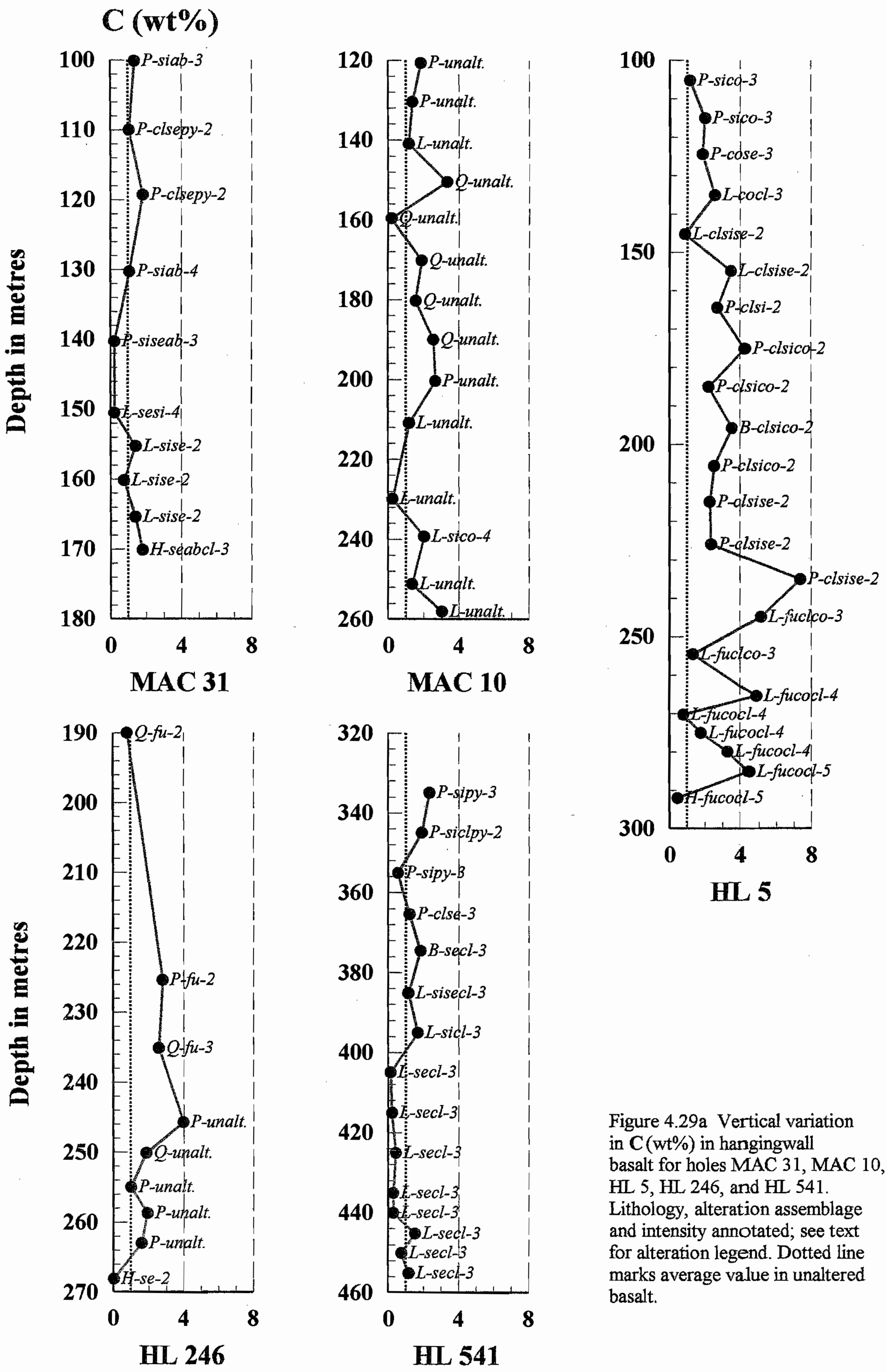


Figure 4.29a Vertical variation in C (wt%) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

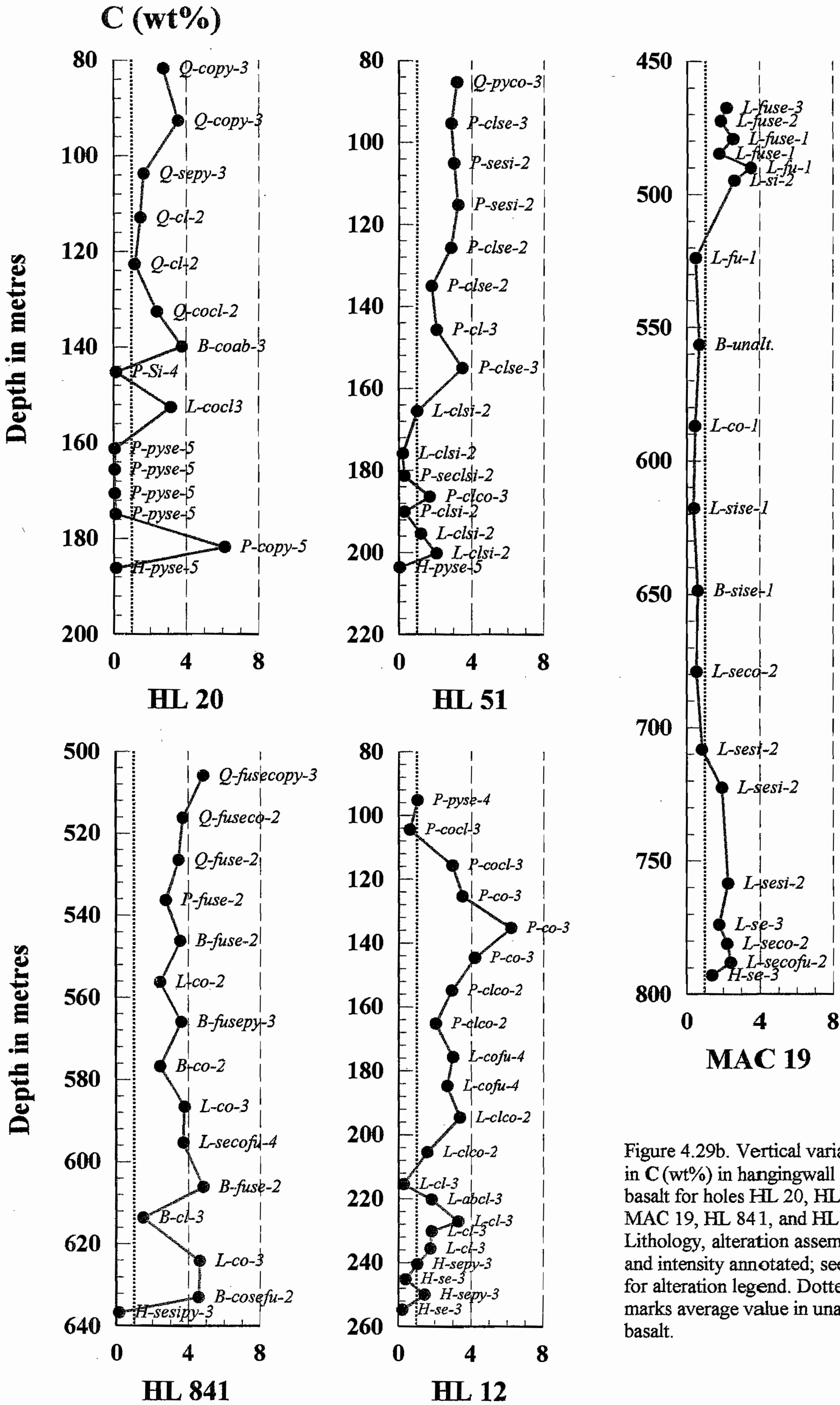


Figure 4.29b. Vertical variation in C (wt%) in hangingwall basalt for holes HL 20, HL 51 MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

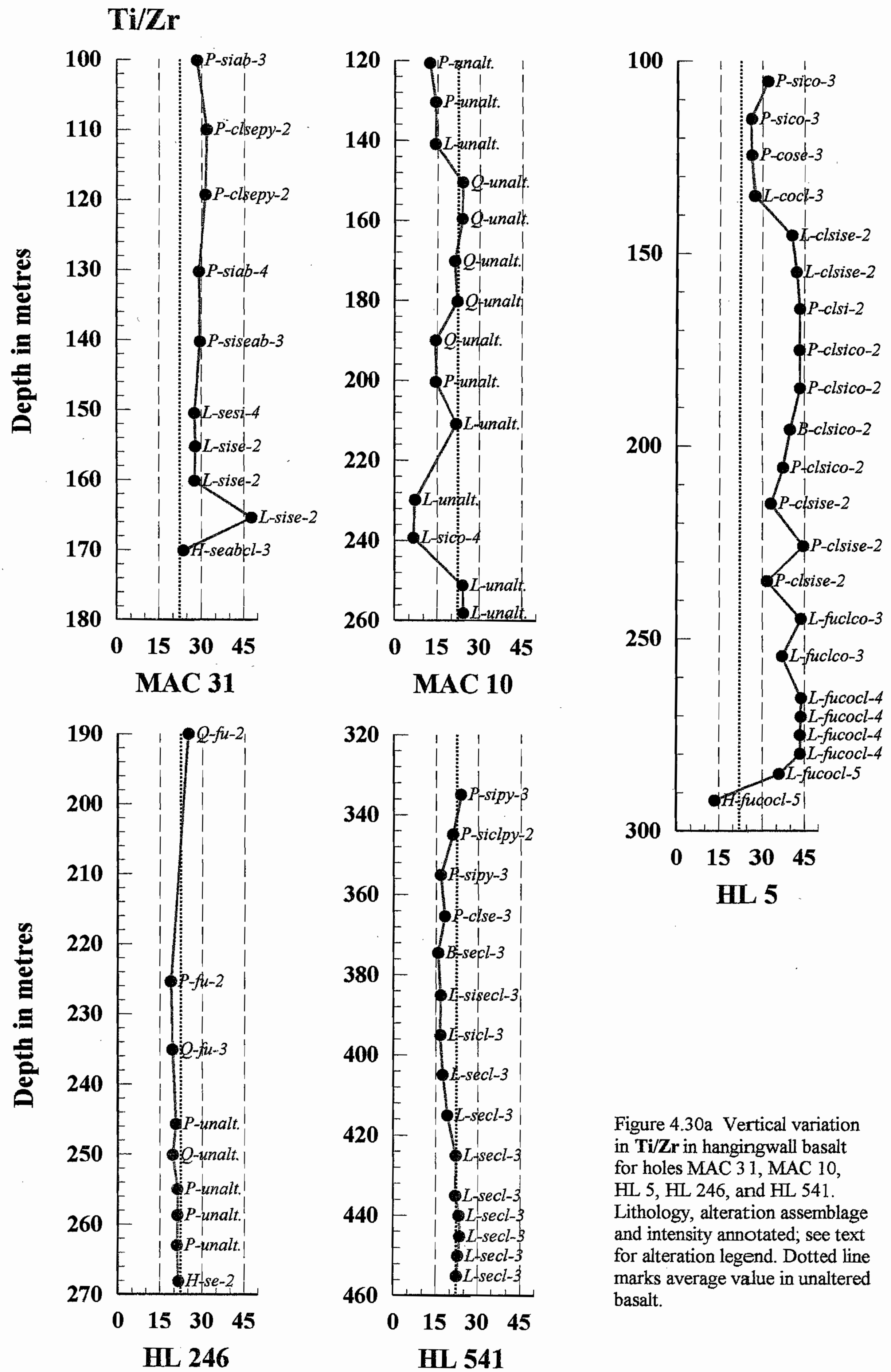


Figure 4.30a Vertical variation in **Ti/Zr** in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

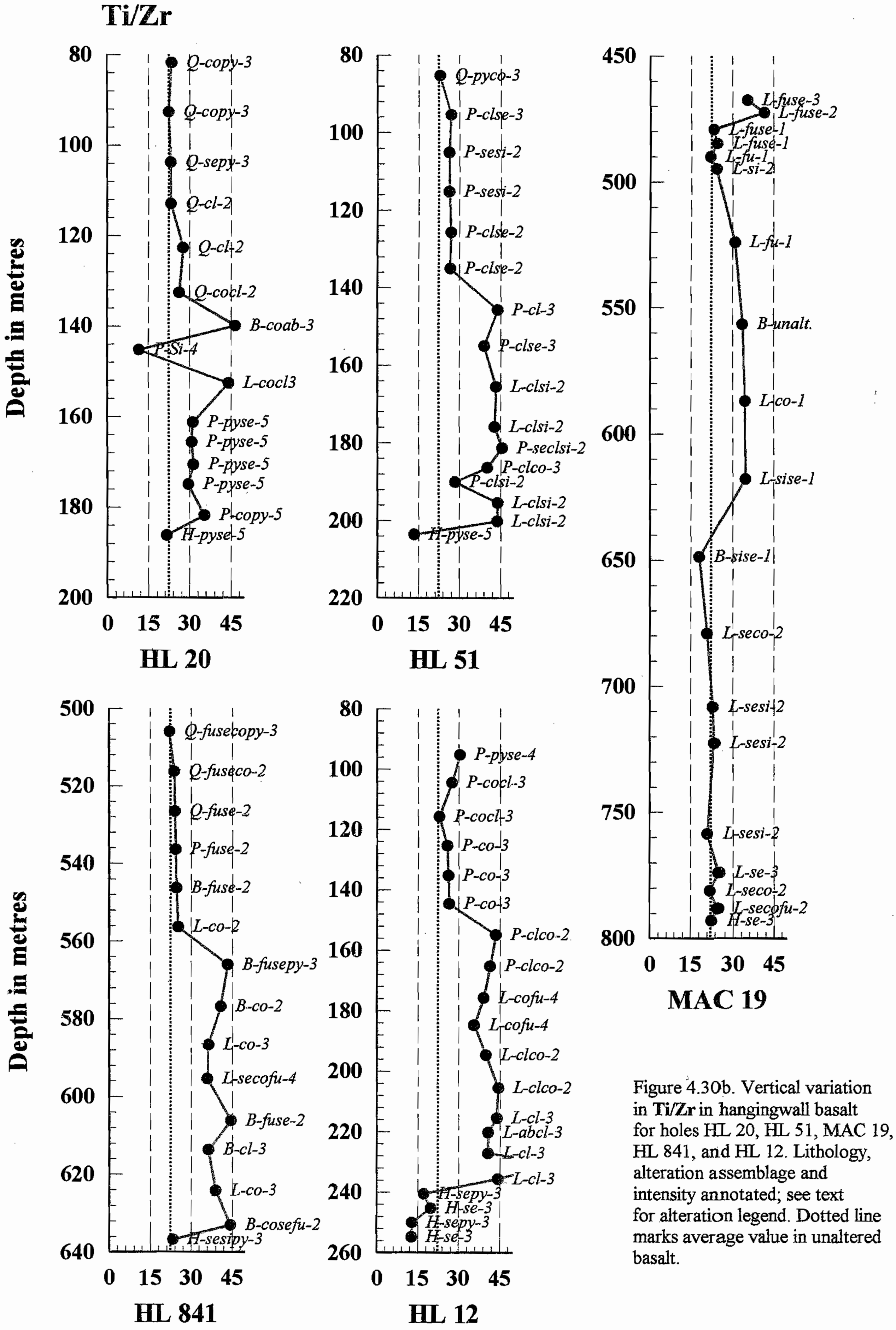


Figure 4.30b. Vertical variation in **Ti/Zr** in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

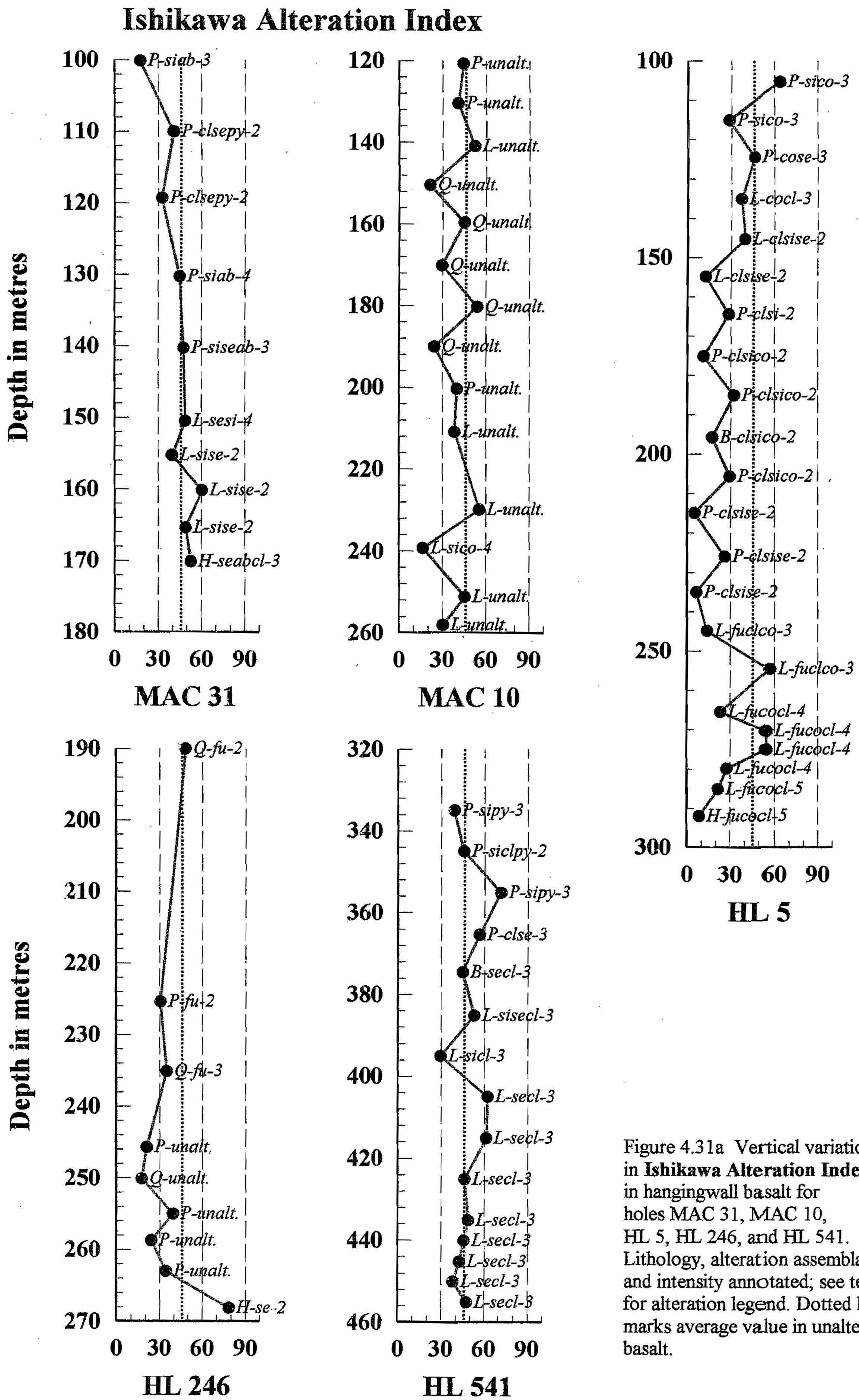


Figure 4.31a Vertical variation in **Ishikawa Alteration Index** in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

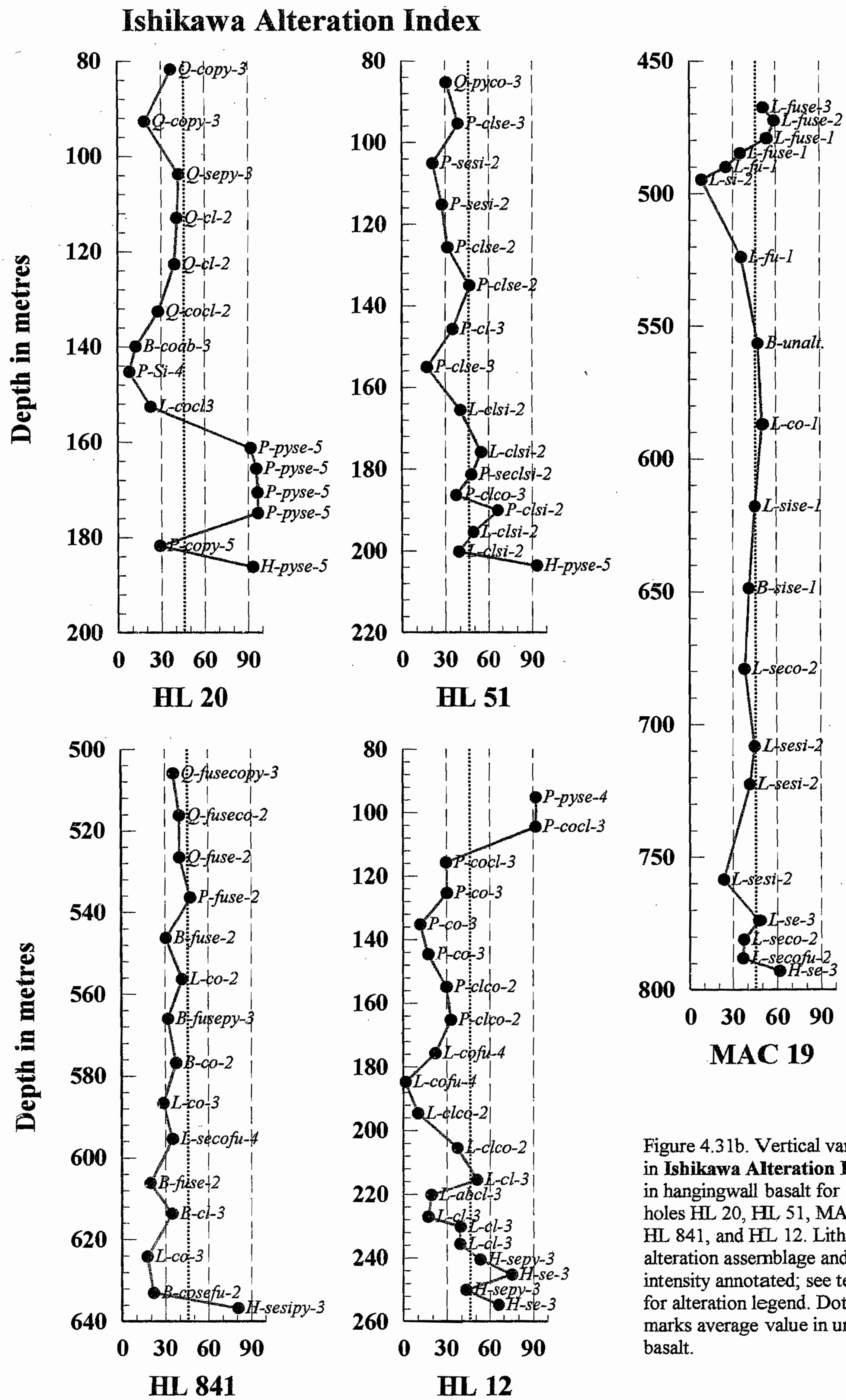


Figure 4.31b. Vertical variation in **Ishikawa Alteration Index** in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

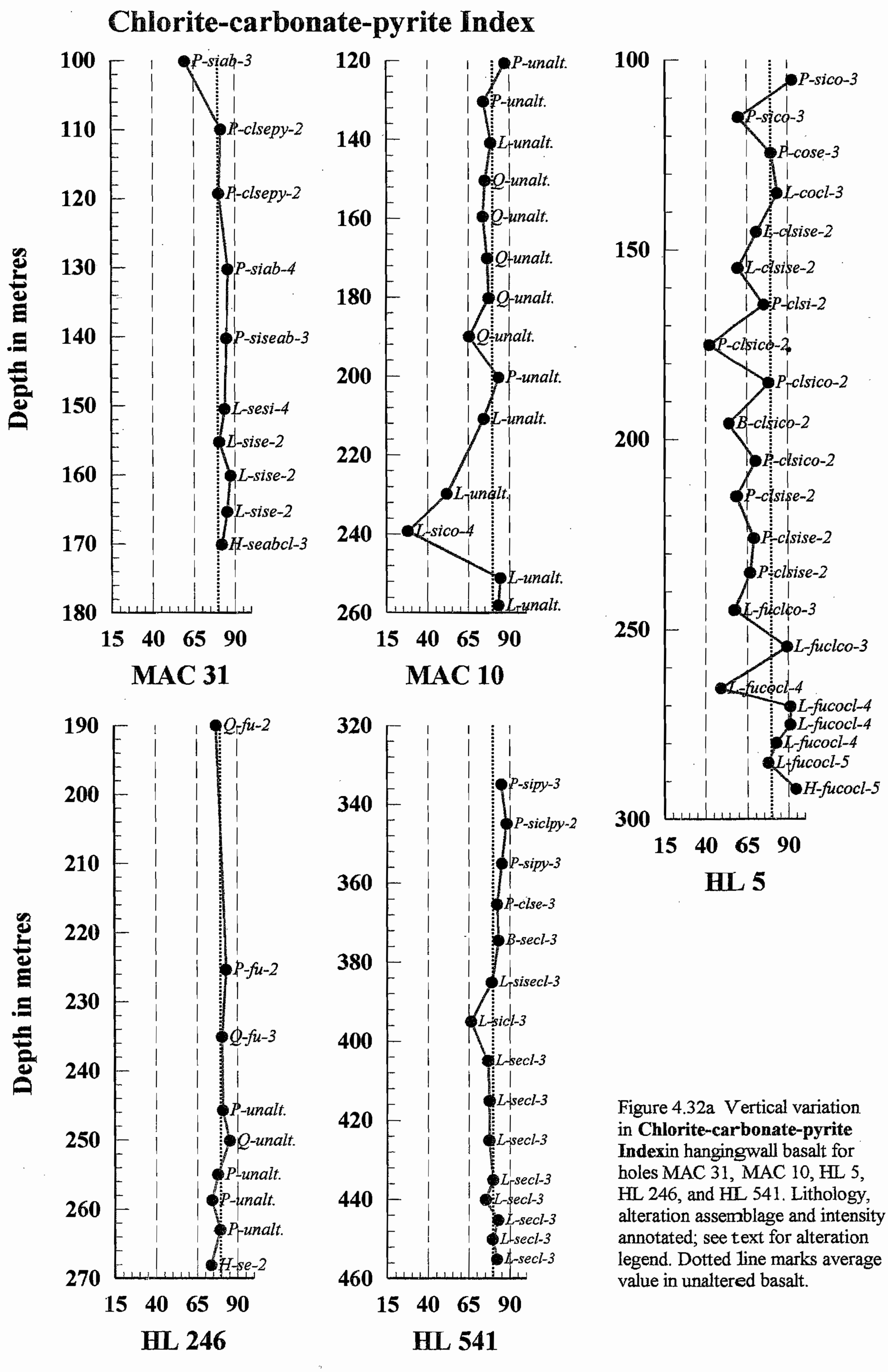


Figure 4.32a Vertical variation in **Chlorite-carbonate-pyrite Index**in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

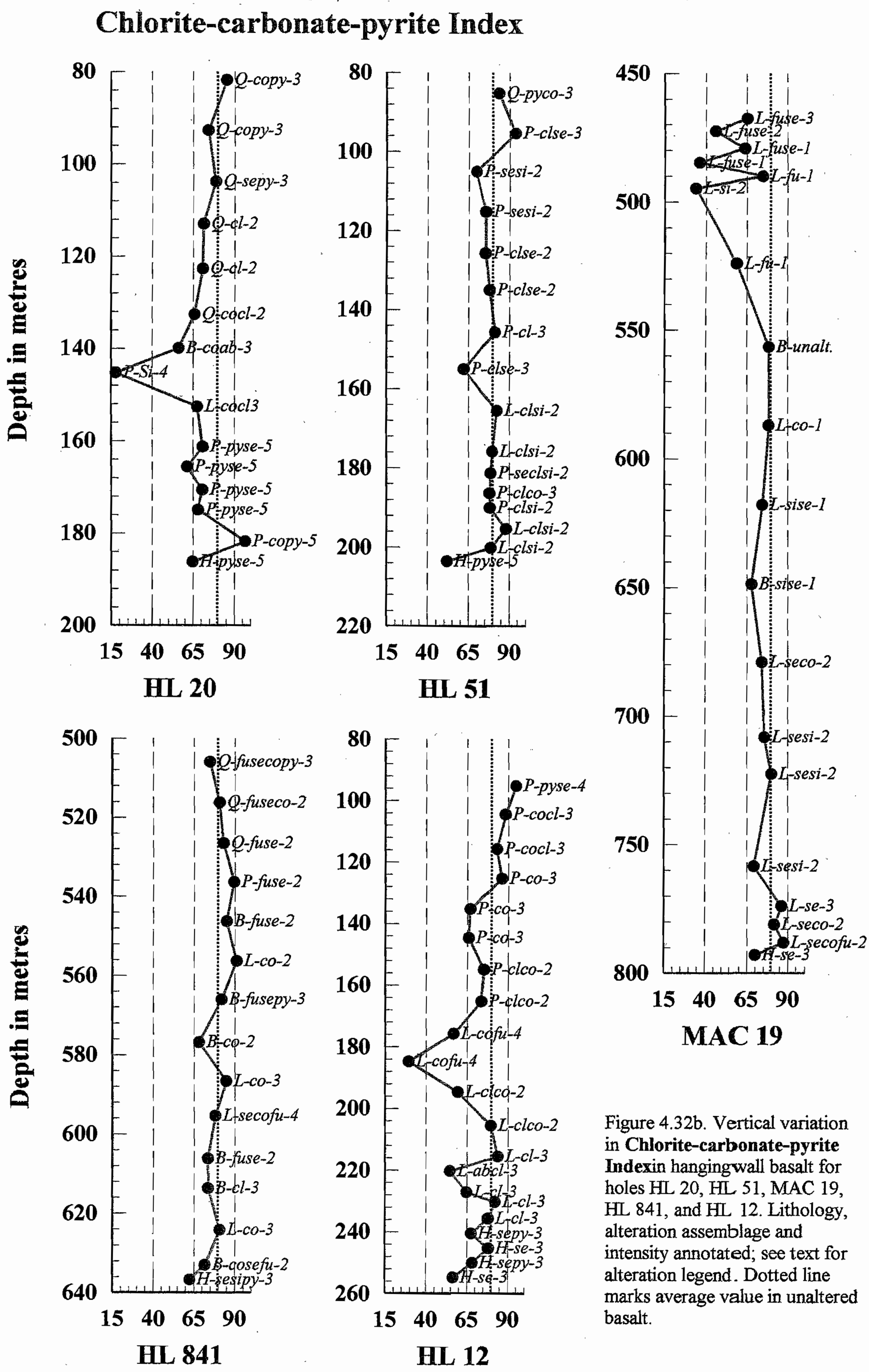
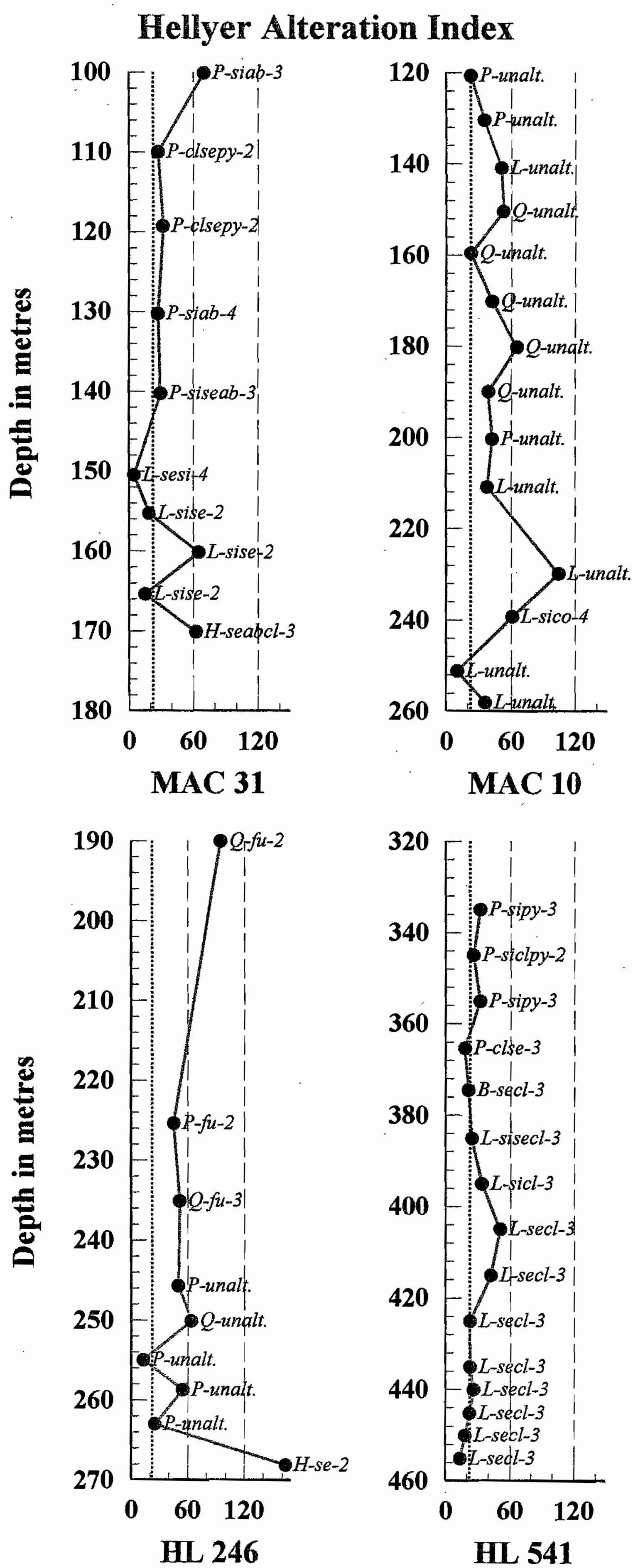


Figure 4.32b. Vertical variation in **Chlorite-carbonate-pyrite Index**in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.



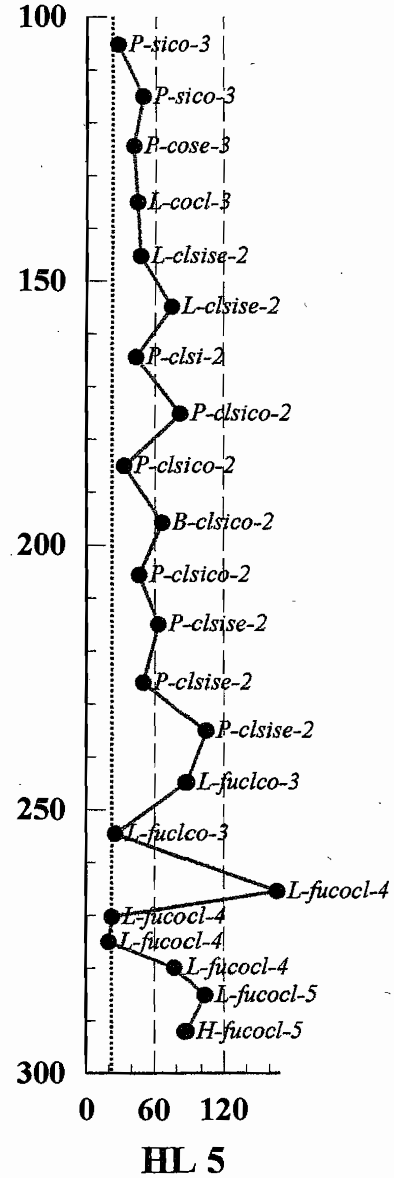


Figure 4.33a. Vertical variation in **Hellyer Alteration Index** in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

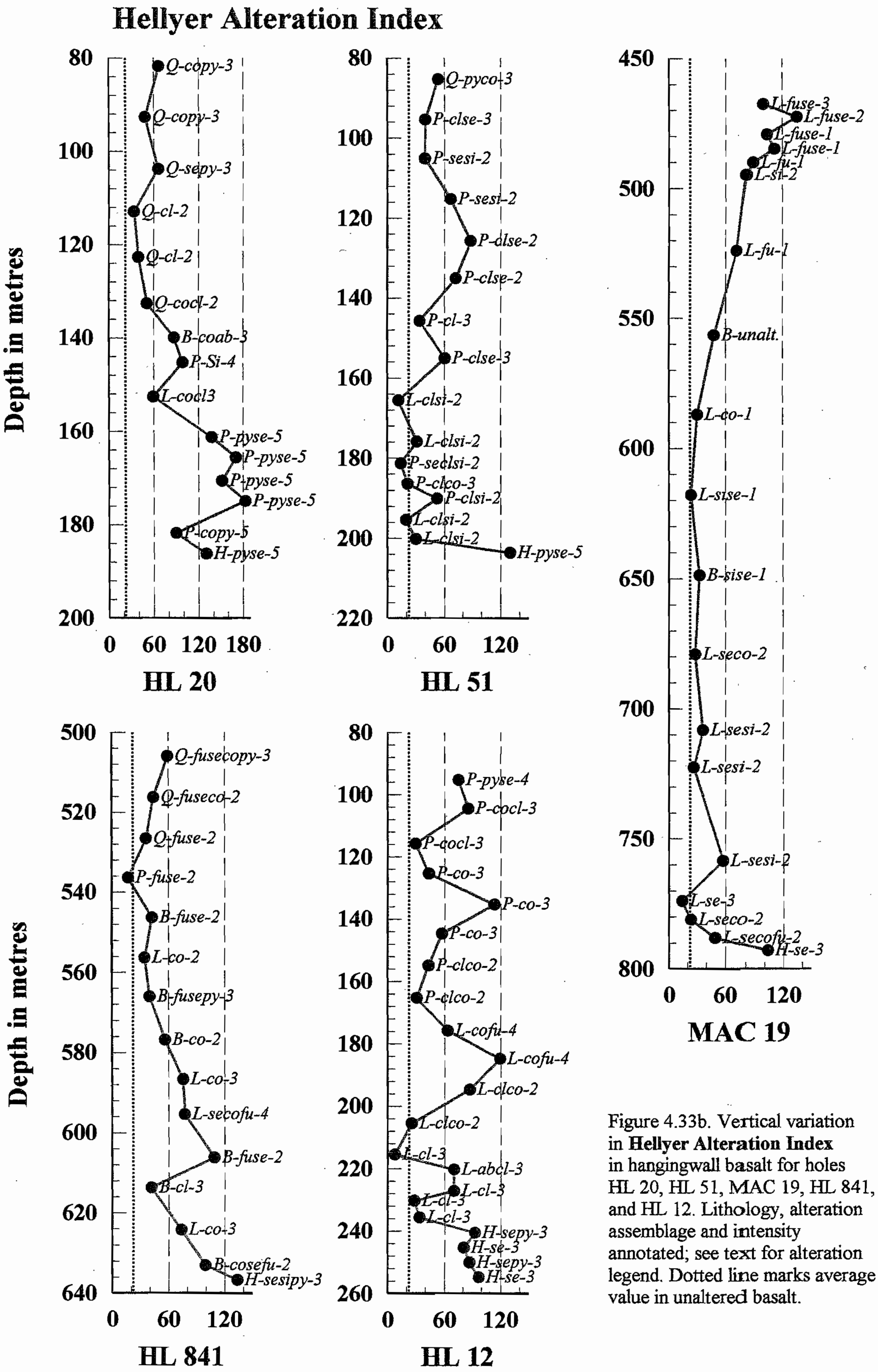


Figure 4.33b. Vertical variation in **Hellyer Alteration Index** in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

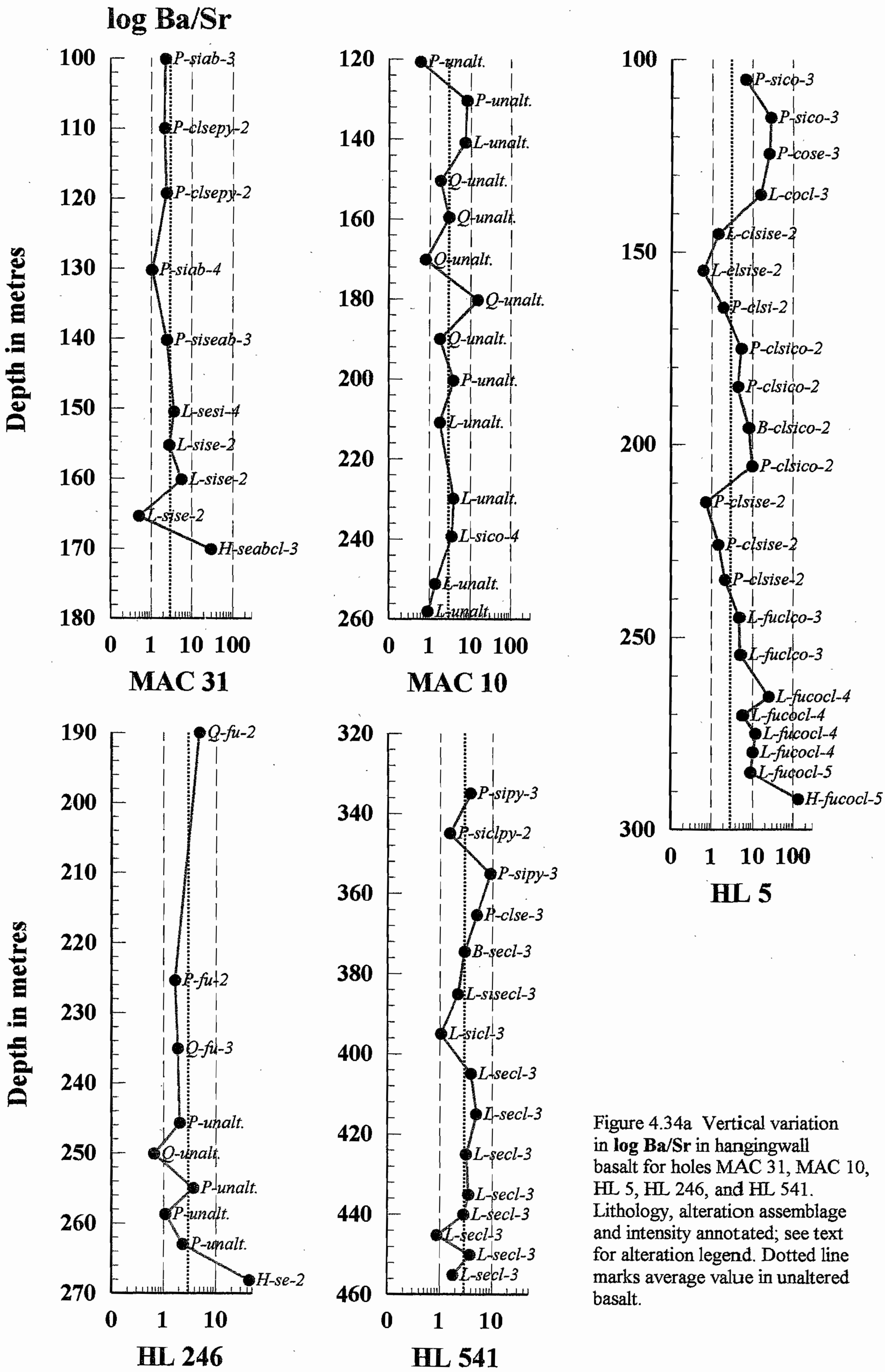


Figure 4.34a Vertical variation in **log Ba/Sr** in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

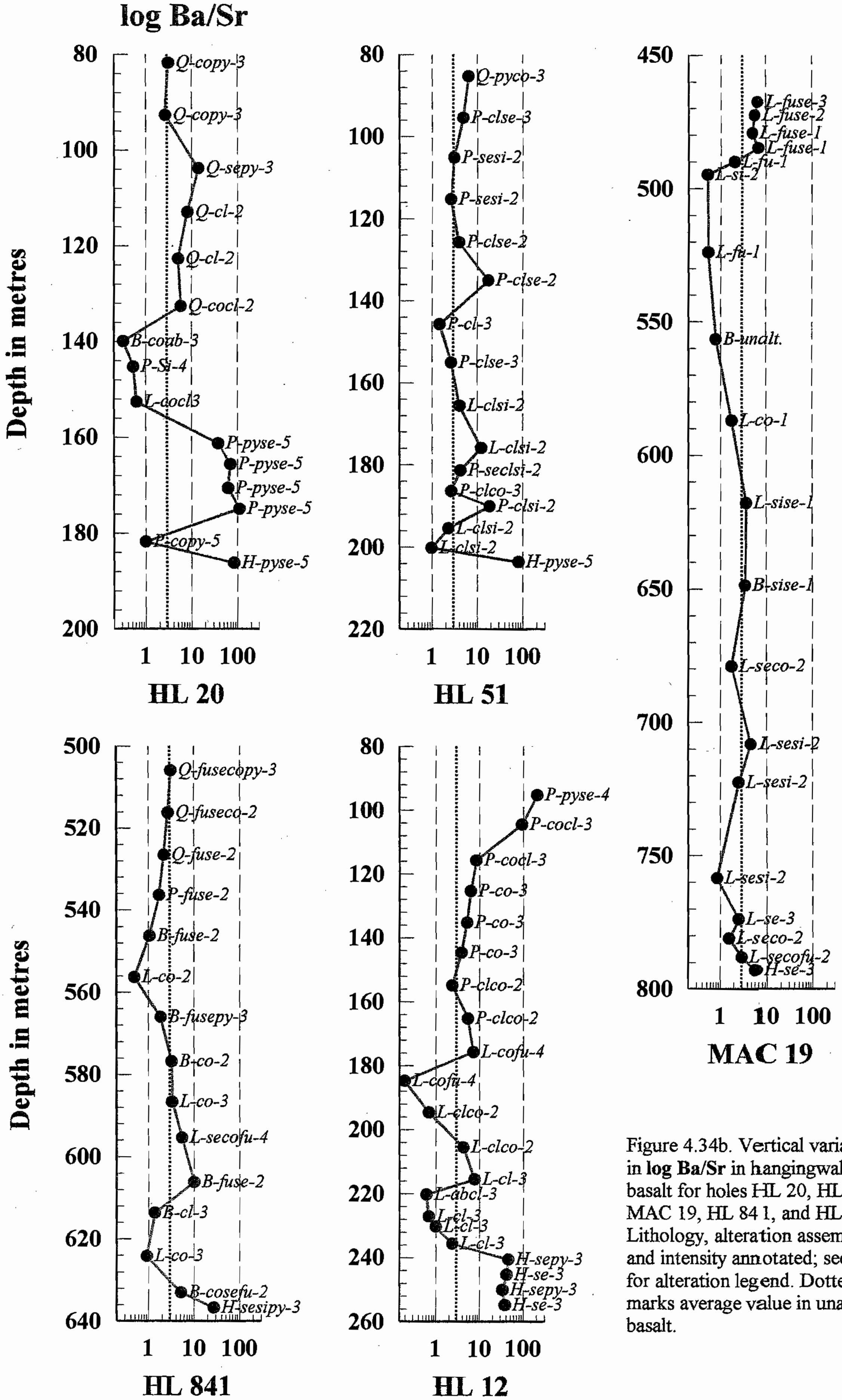


Figure 4.34b. Vertical variation in **log Ba/Sr** in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 84 1, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

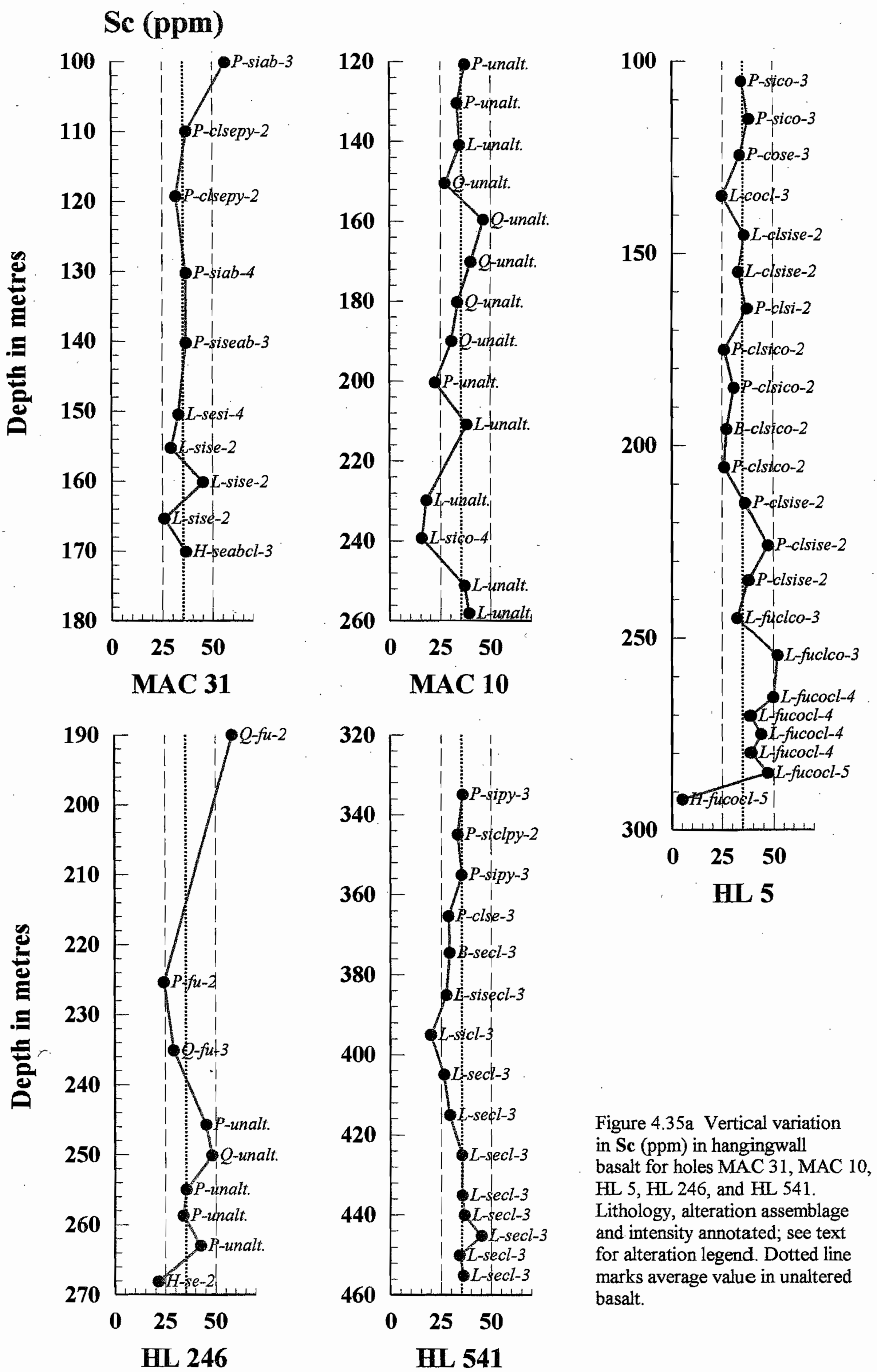


Figure 4.35a Vertical variation in Sc (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

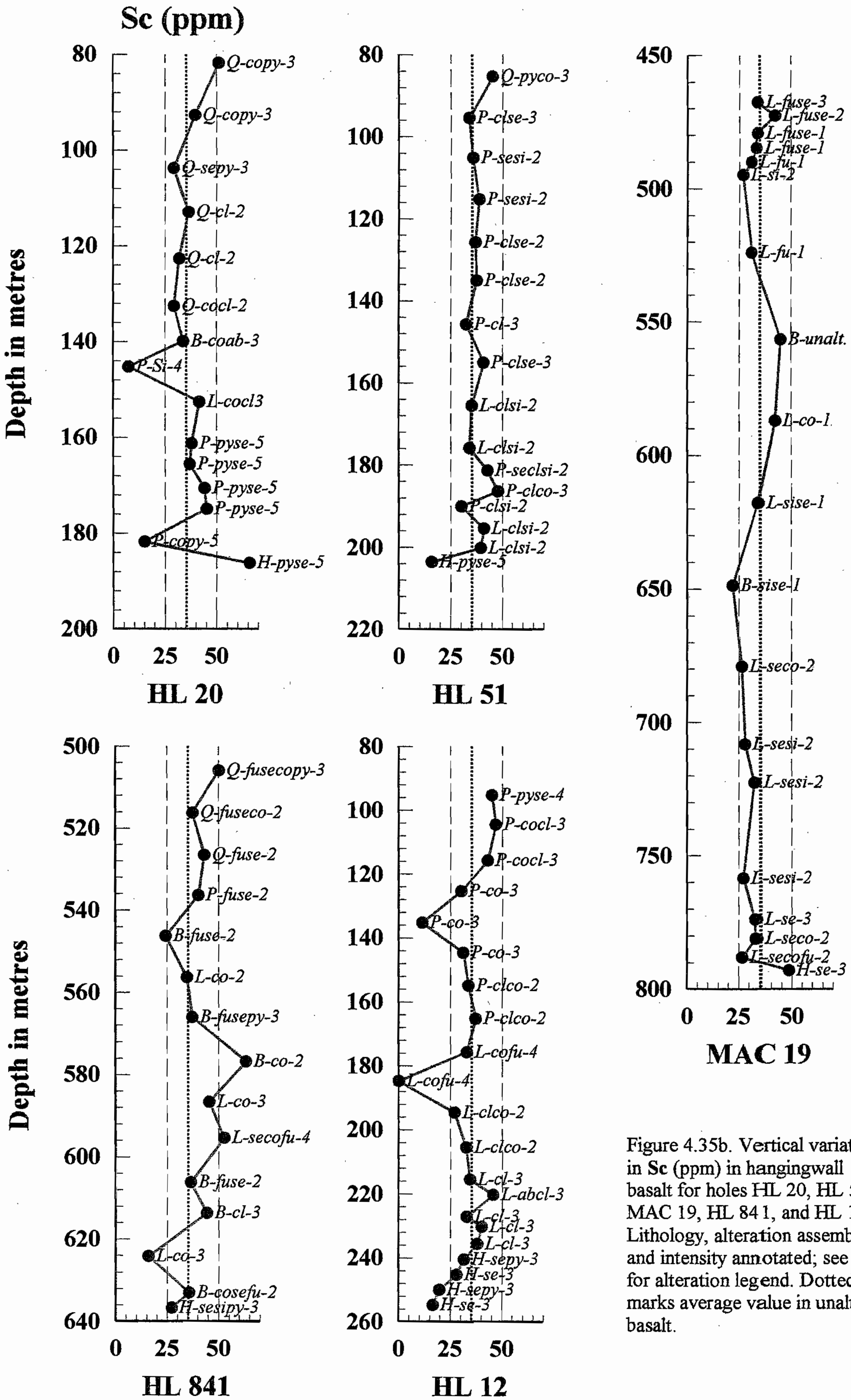


Figure 4.35b. Vertical variation in Sc (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

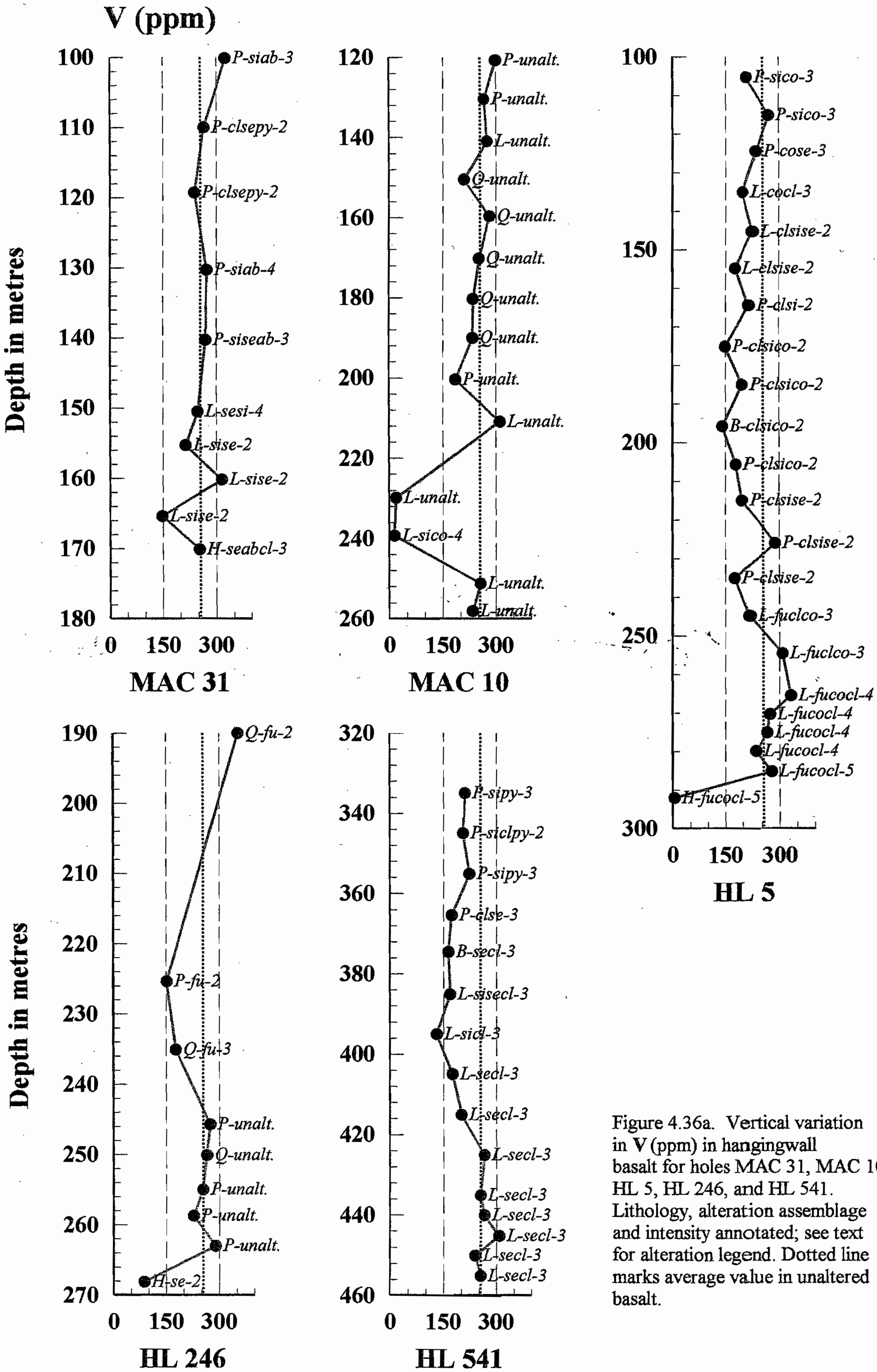


Figure 4.36a. Vertical variation in V (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

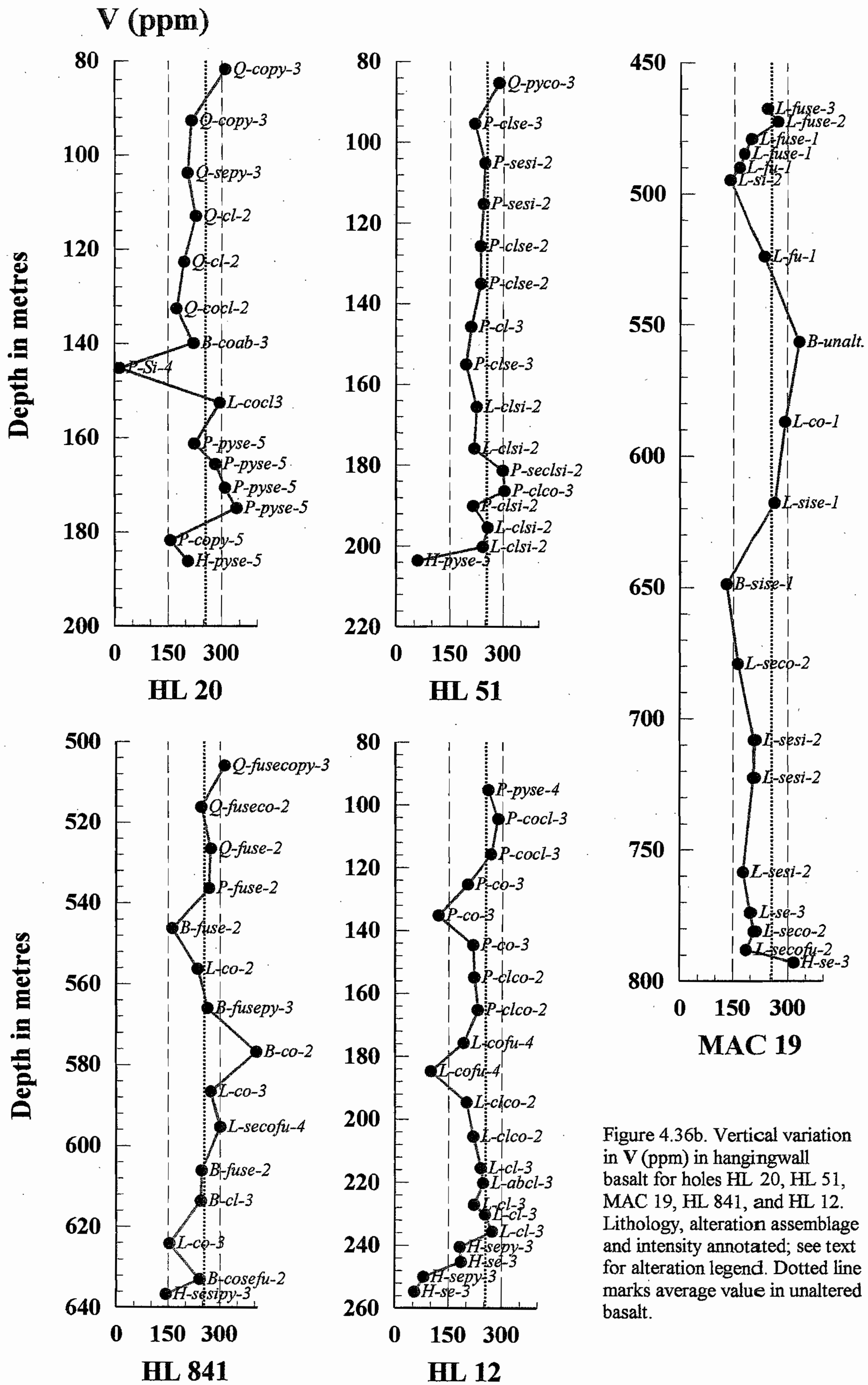


Figure 4.36b. Vertical variation in V (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

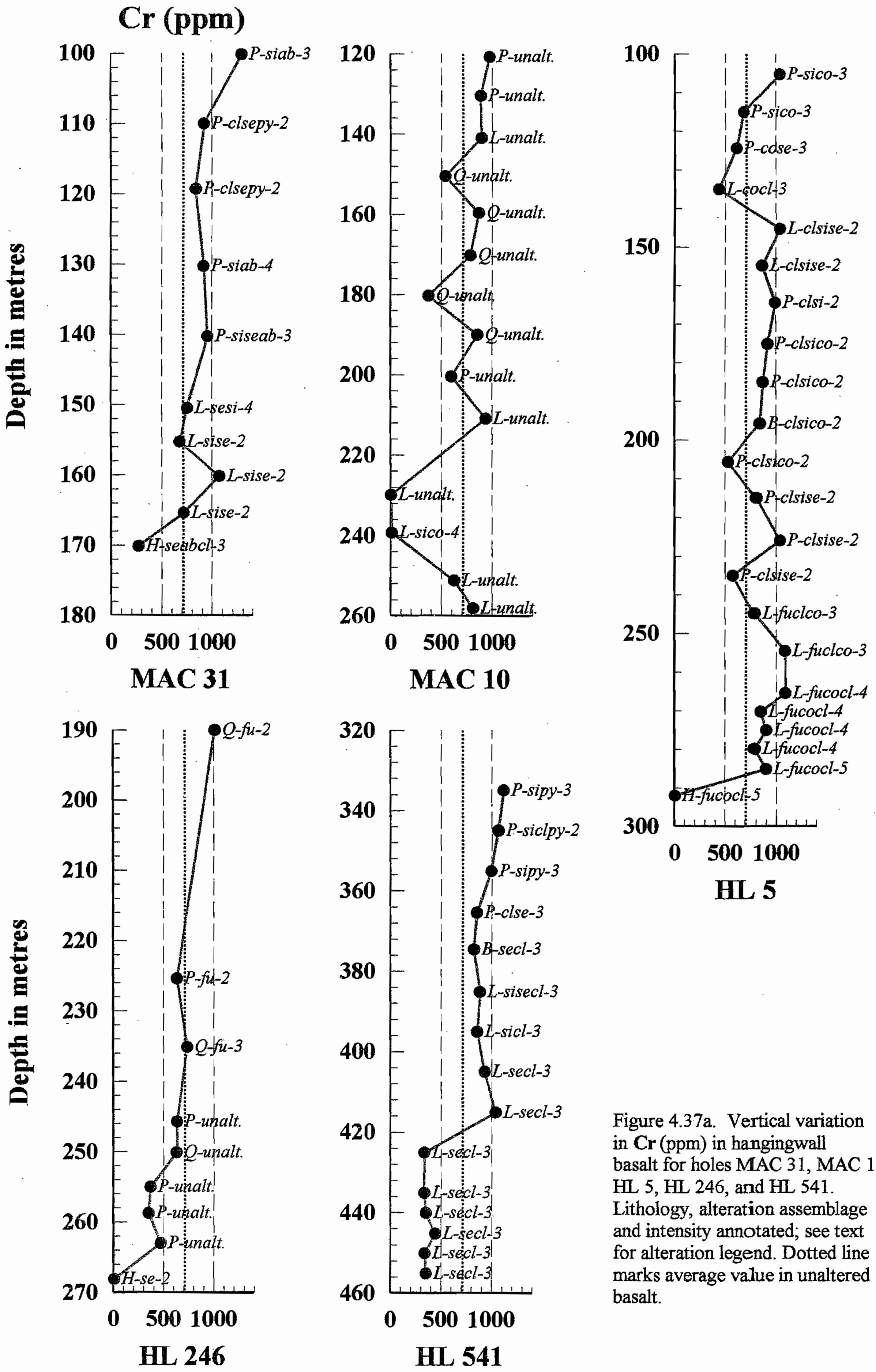


Figure 4.37a. Vertical variation in **Cr** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

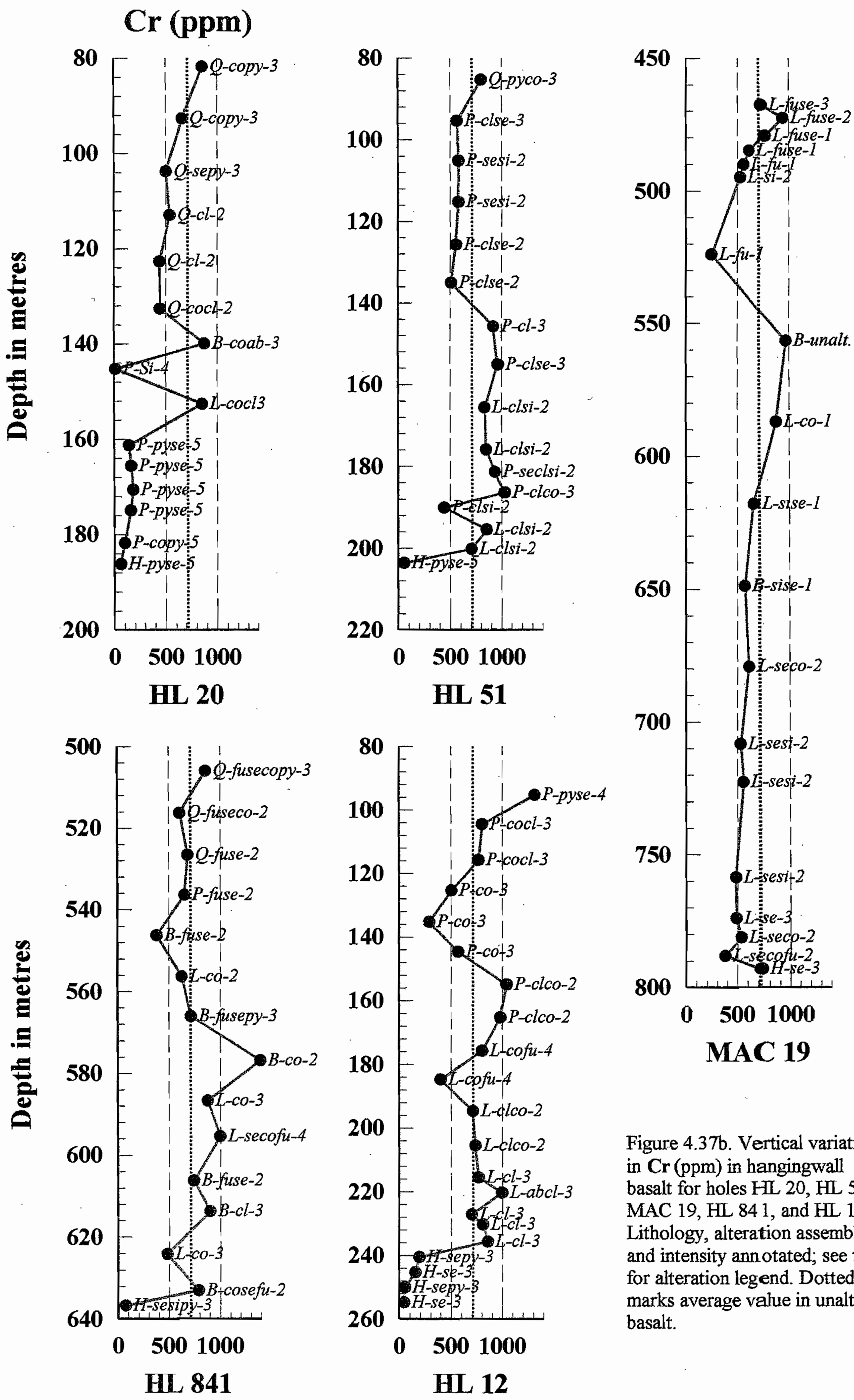


Figure 4.37b. Vertical variation in **Cr** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 84 1, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

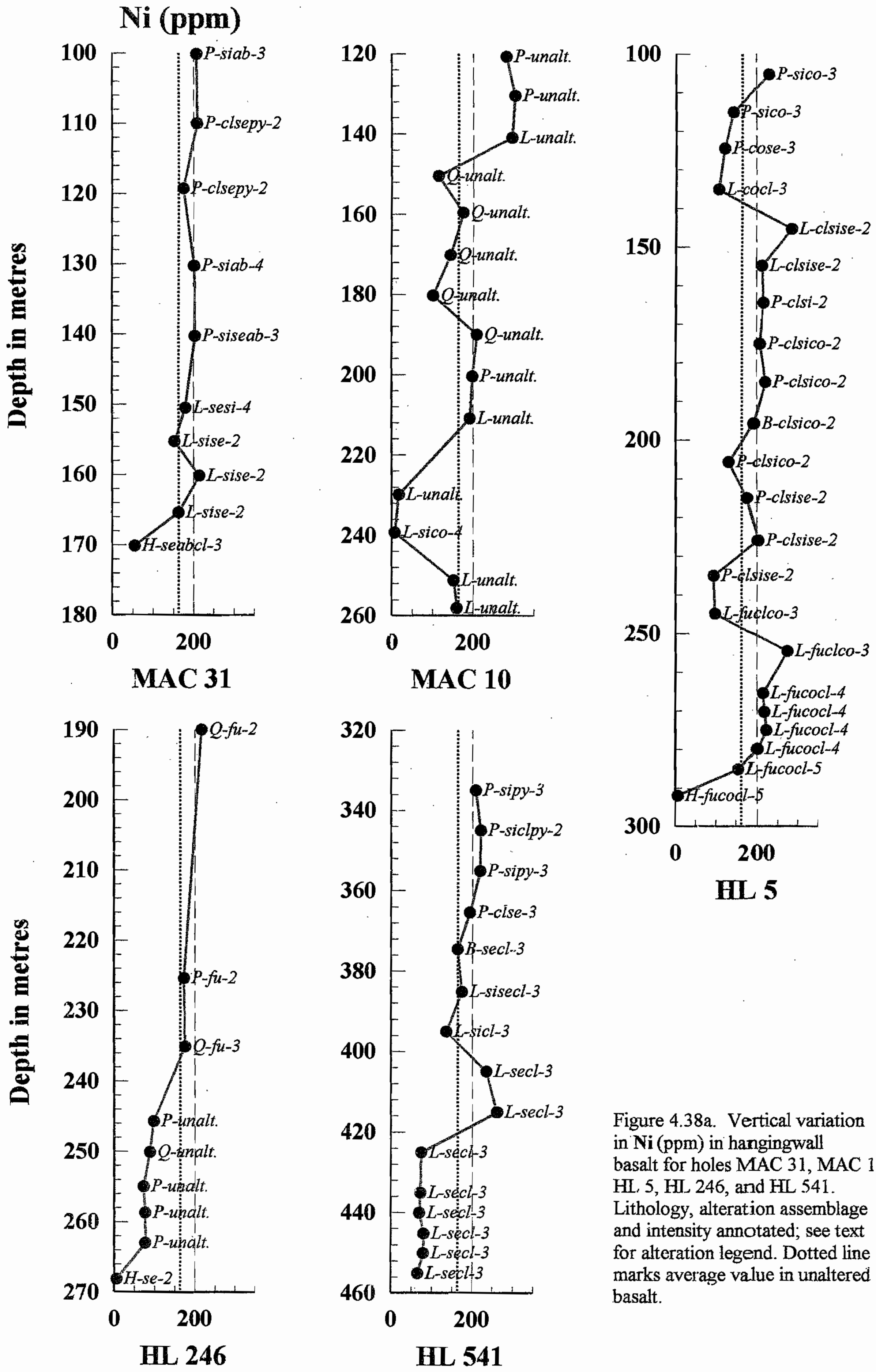


Figure 4.38a. Vertical variation in **Ni** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

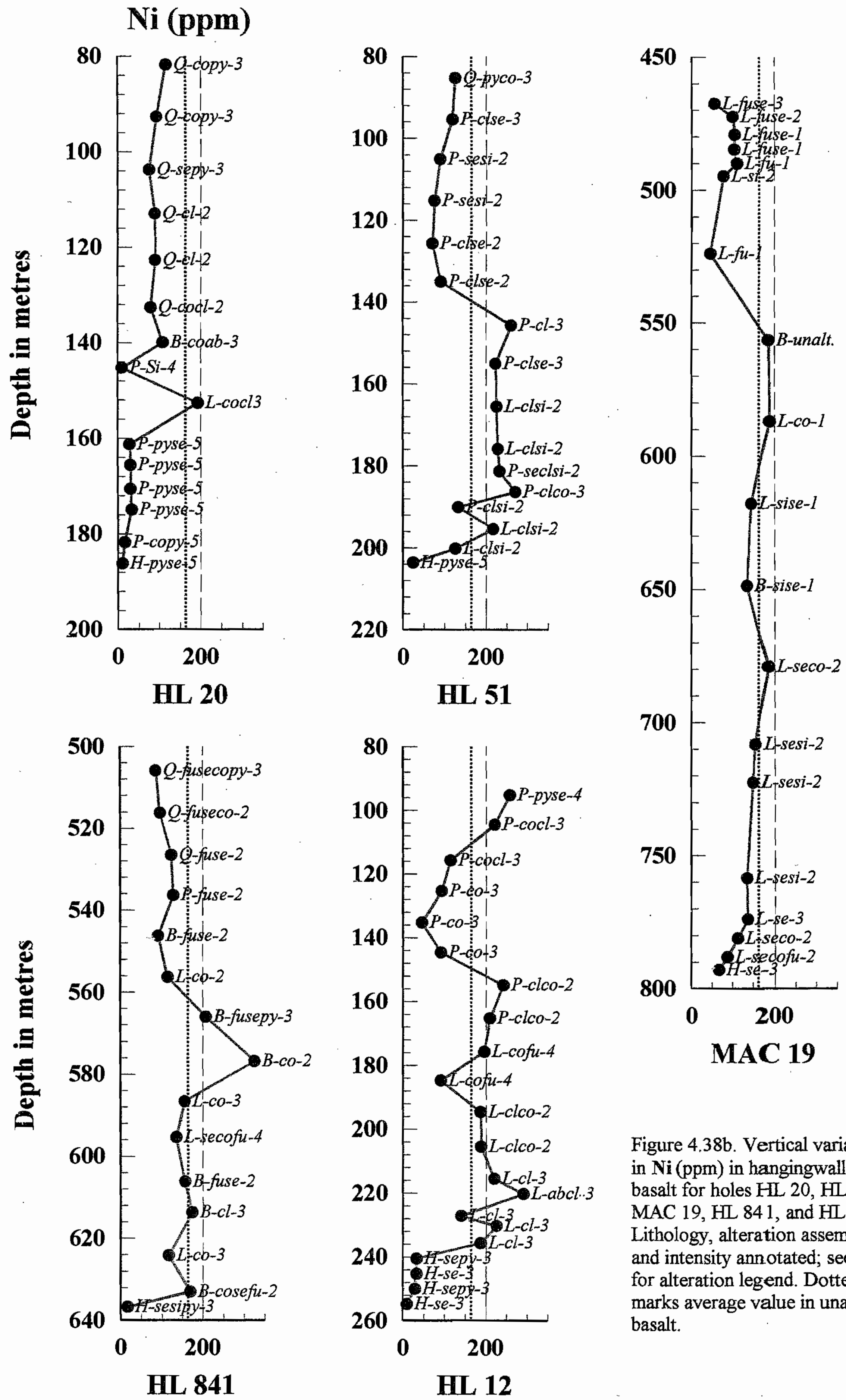


Figure 4.38b. Vertical variation in Ni (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

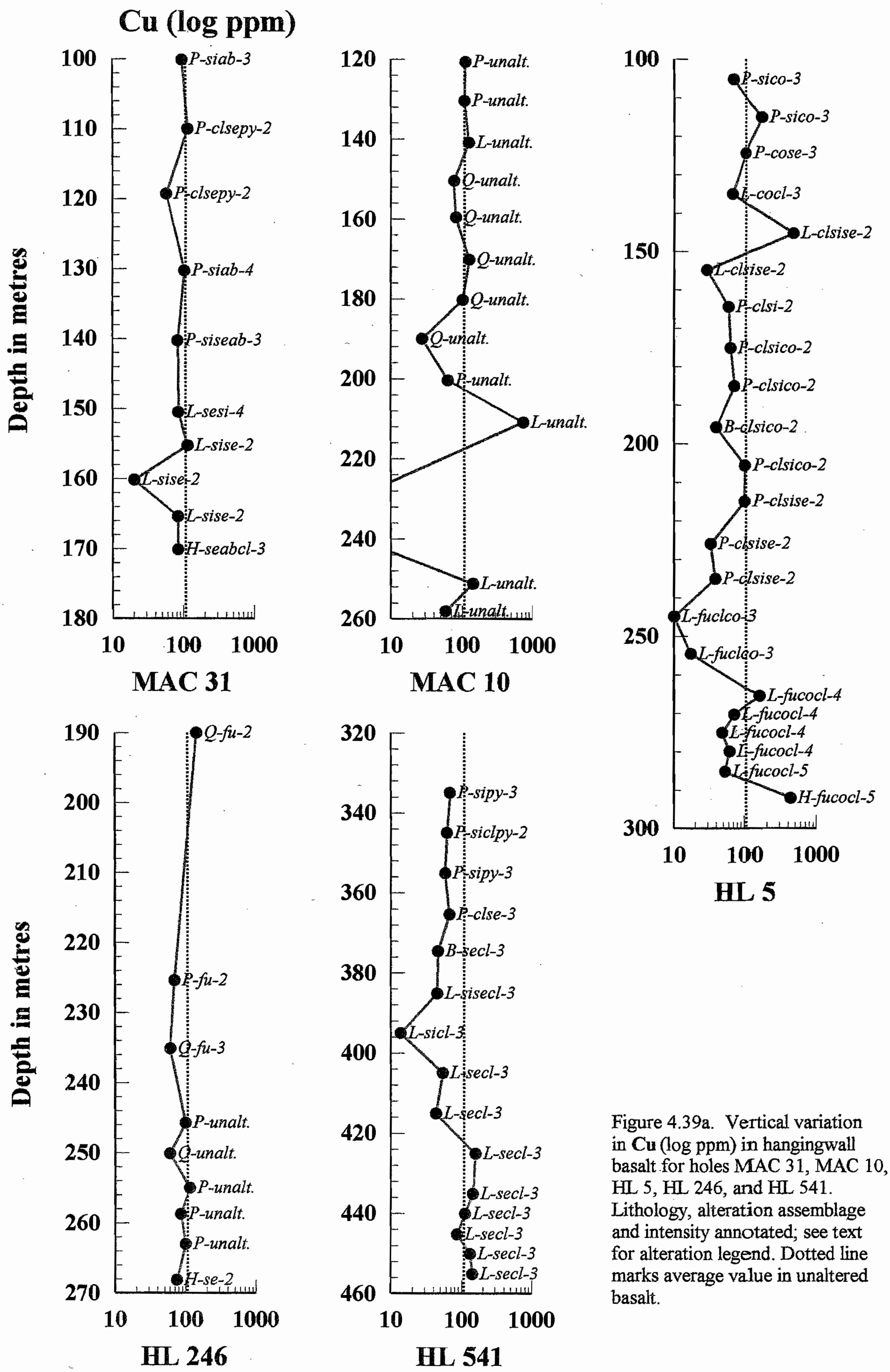


Figure 4.39a. Vertical variation in **Cu** (log ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

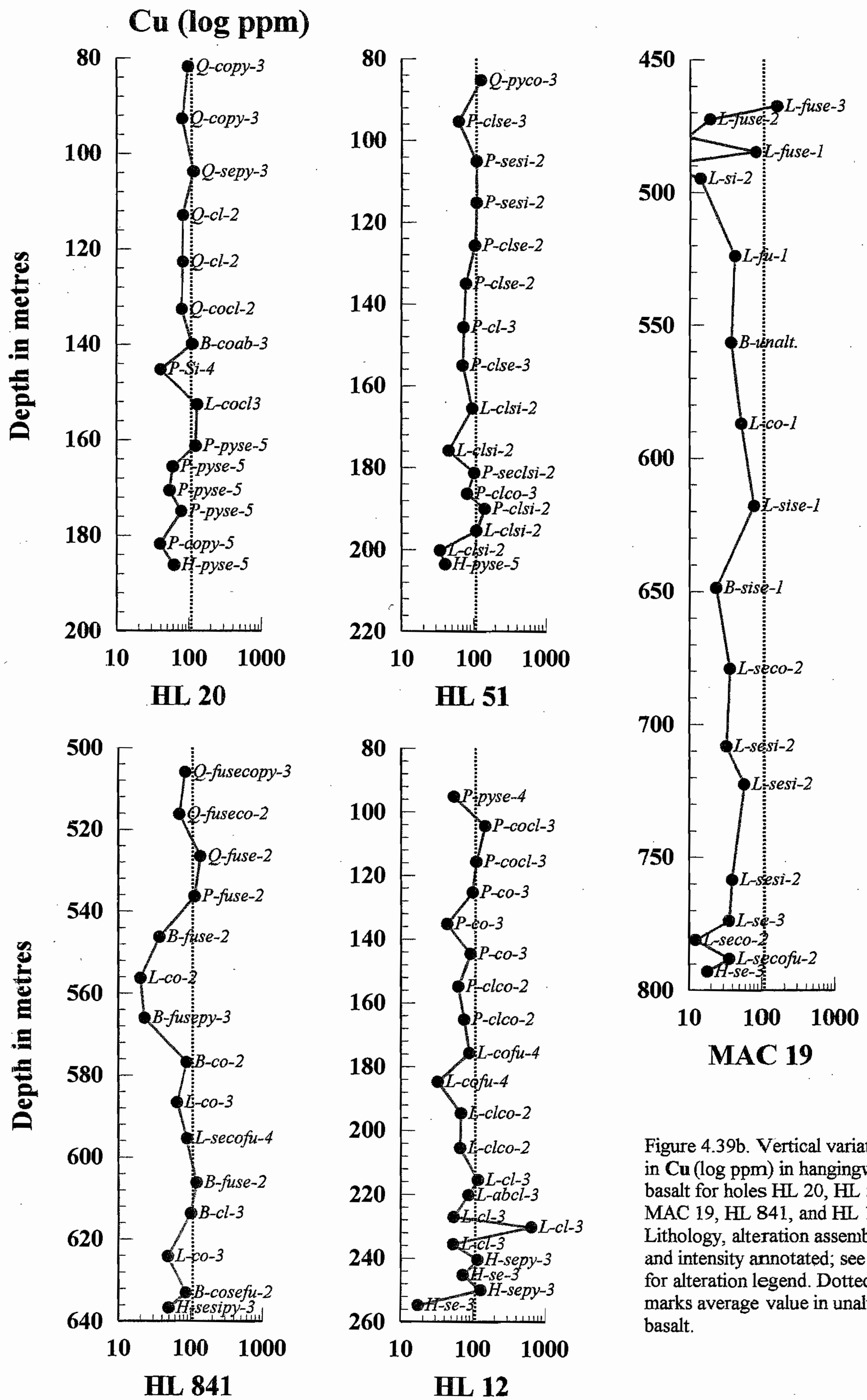


Figure 4.39b. Vertical variation in **Cu** (log ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

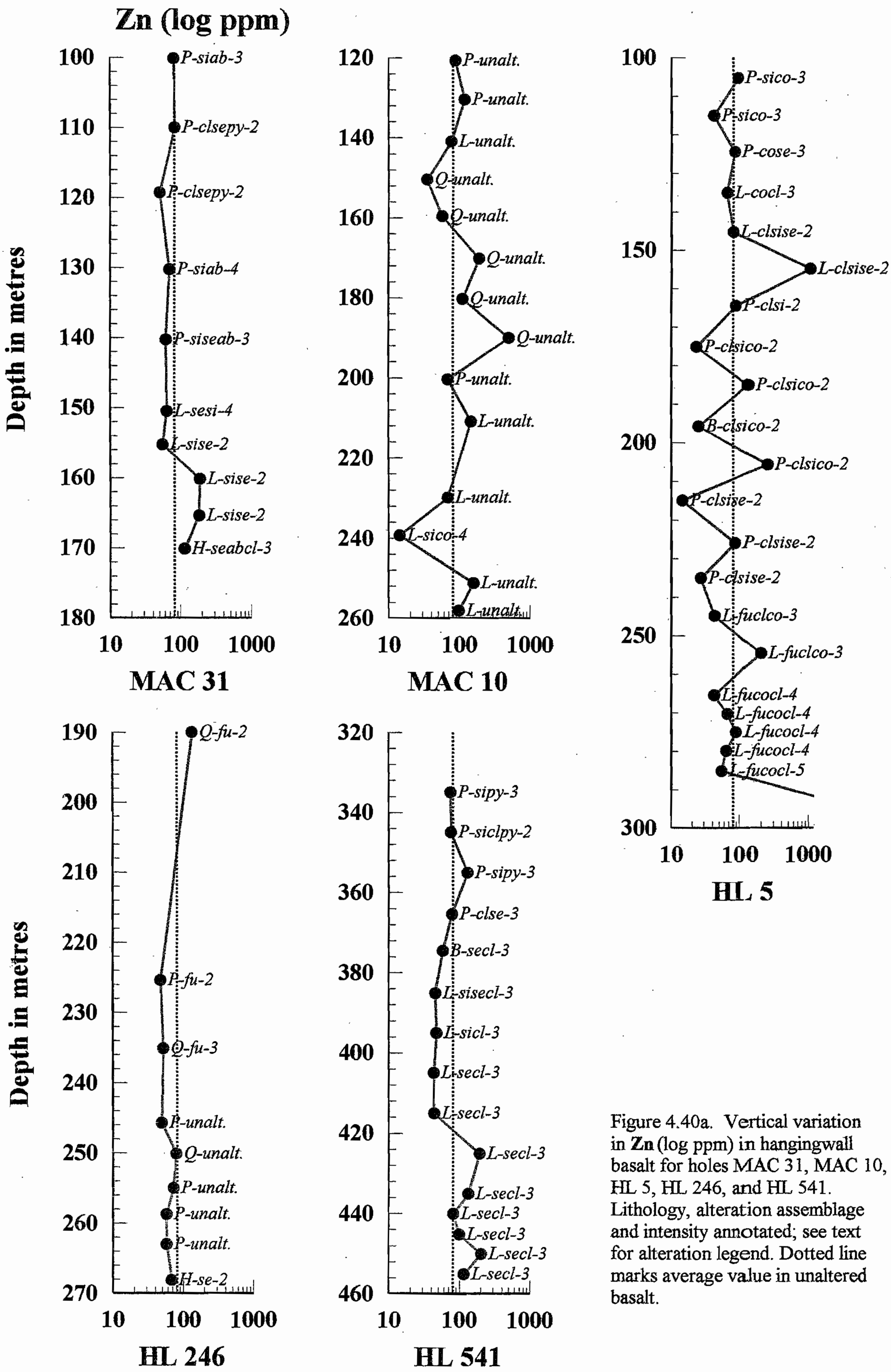


Figure 4.40a. Vertical variation in **Zn** (log ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

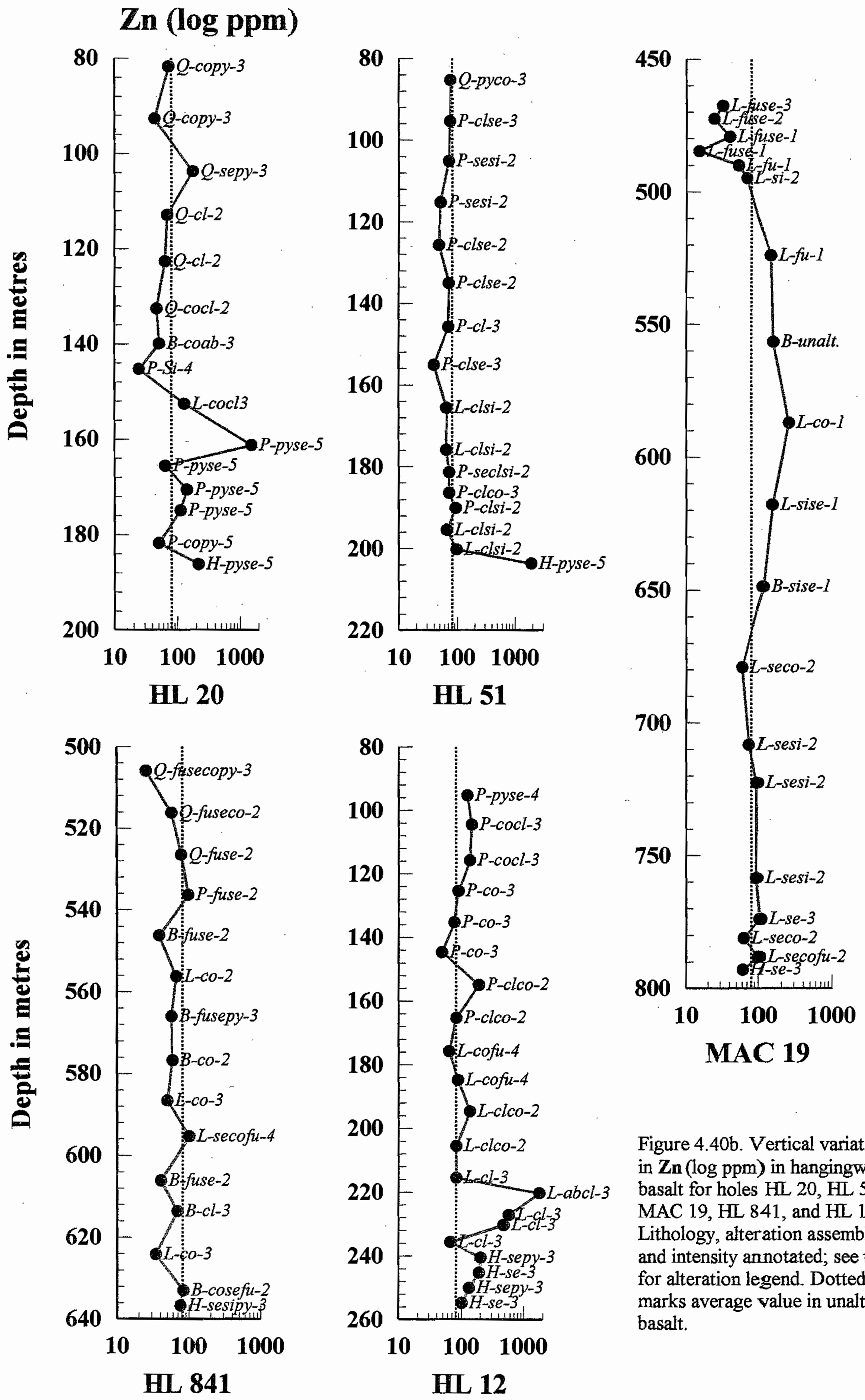


Figure 4.40b. Vertical variation in **Zn** (log ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

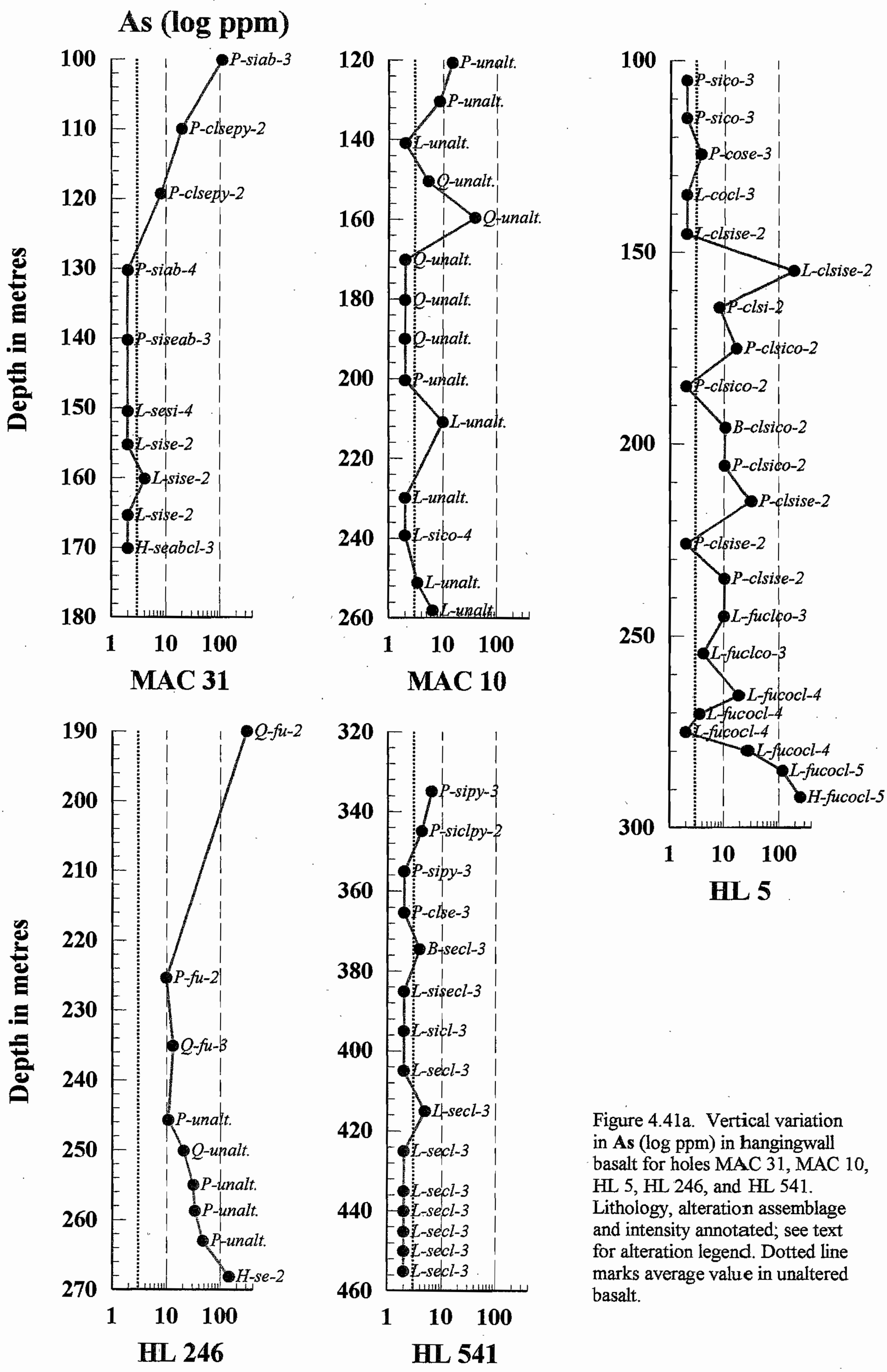


Figure 4.41a. Vertical variation in As (log ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

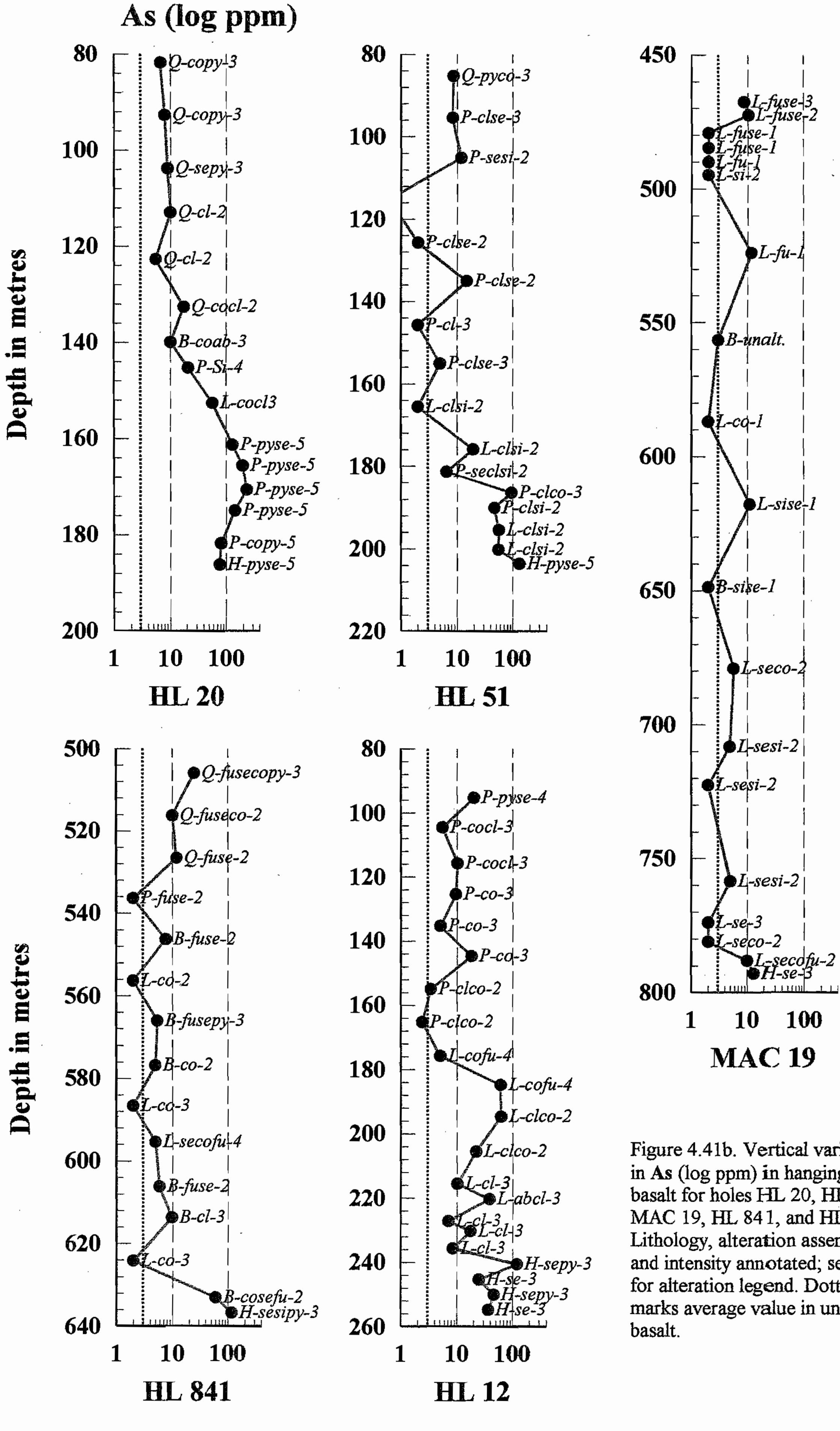


Figure 4.41b. Vertical variation in As (log ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

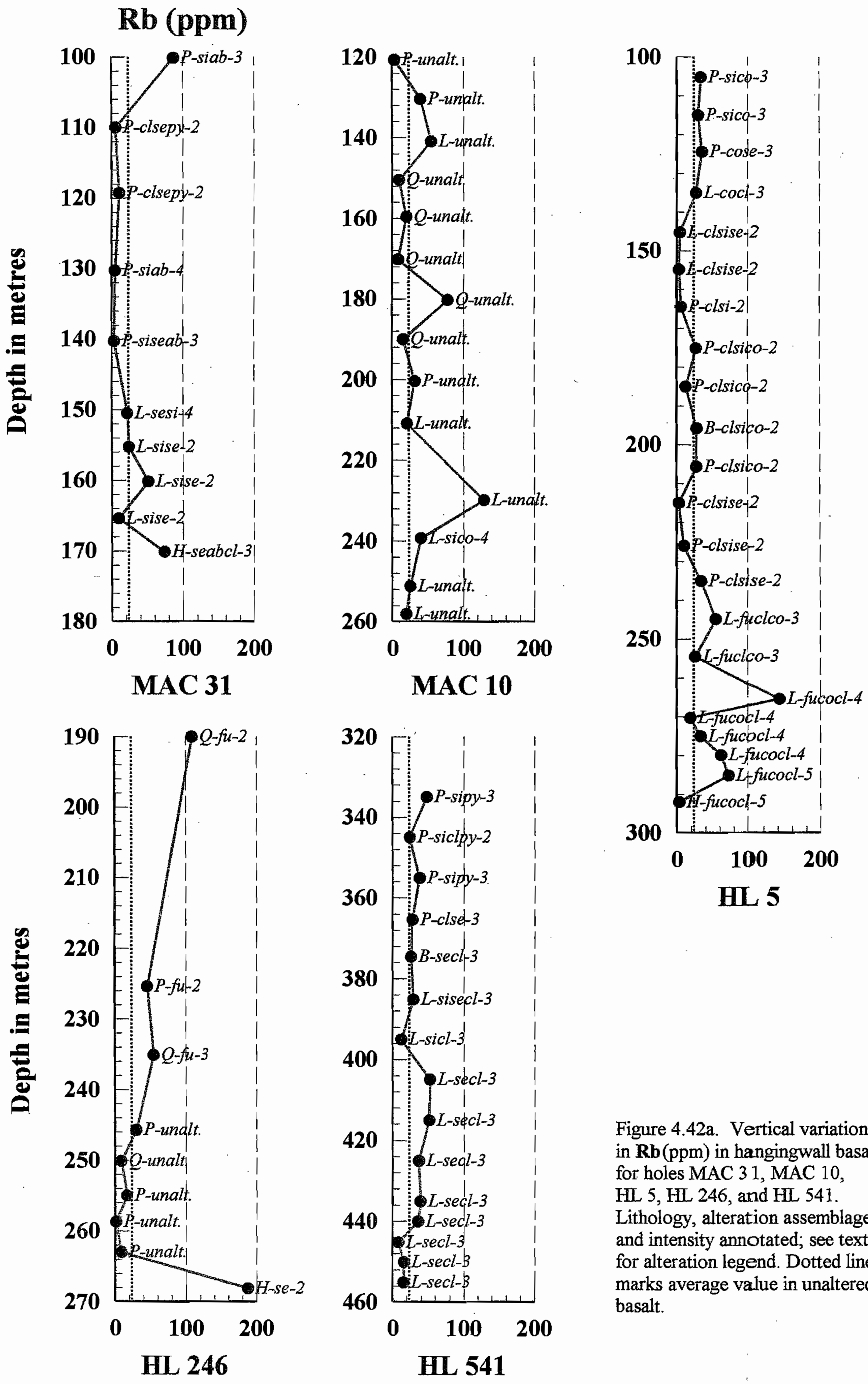


Figure 4.42a. Vertical variation in **Rb** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

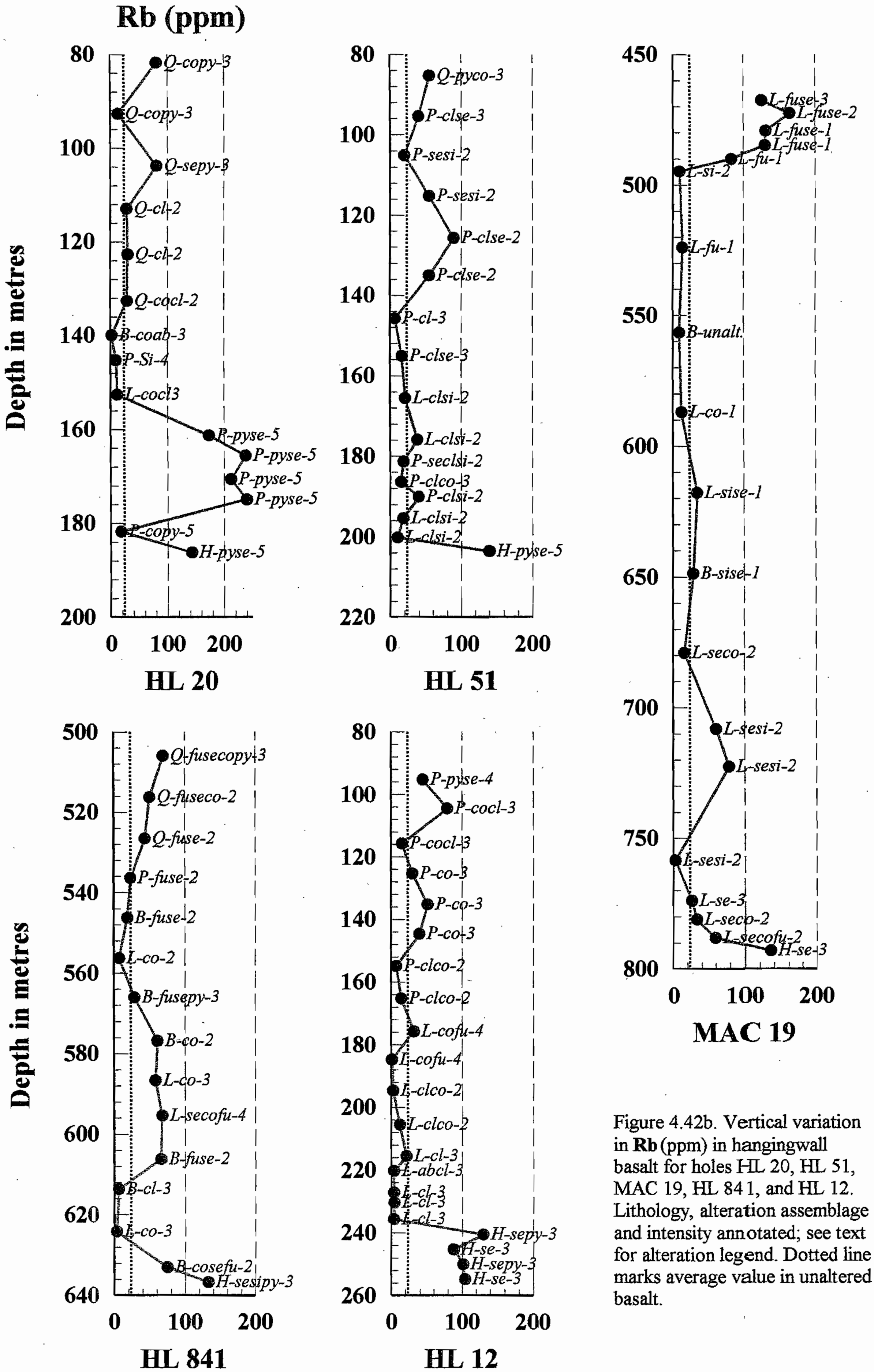


Figure 4.42b. Vertical variation in **Rb** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

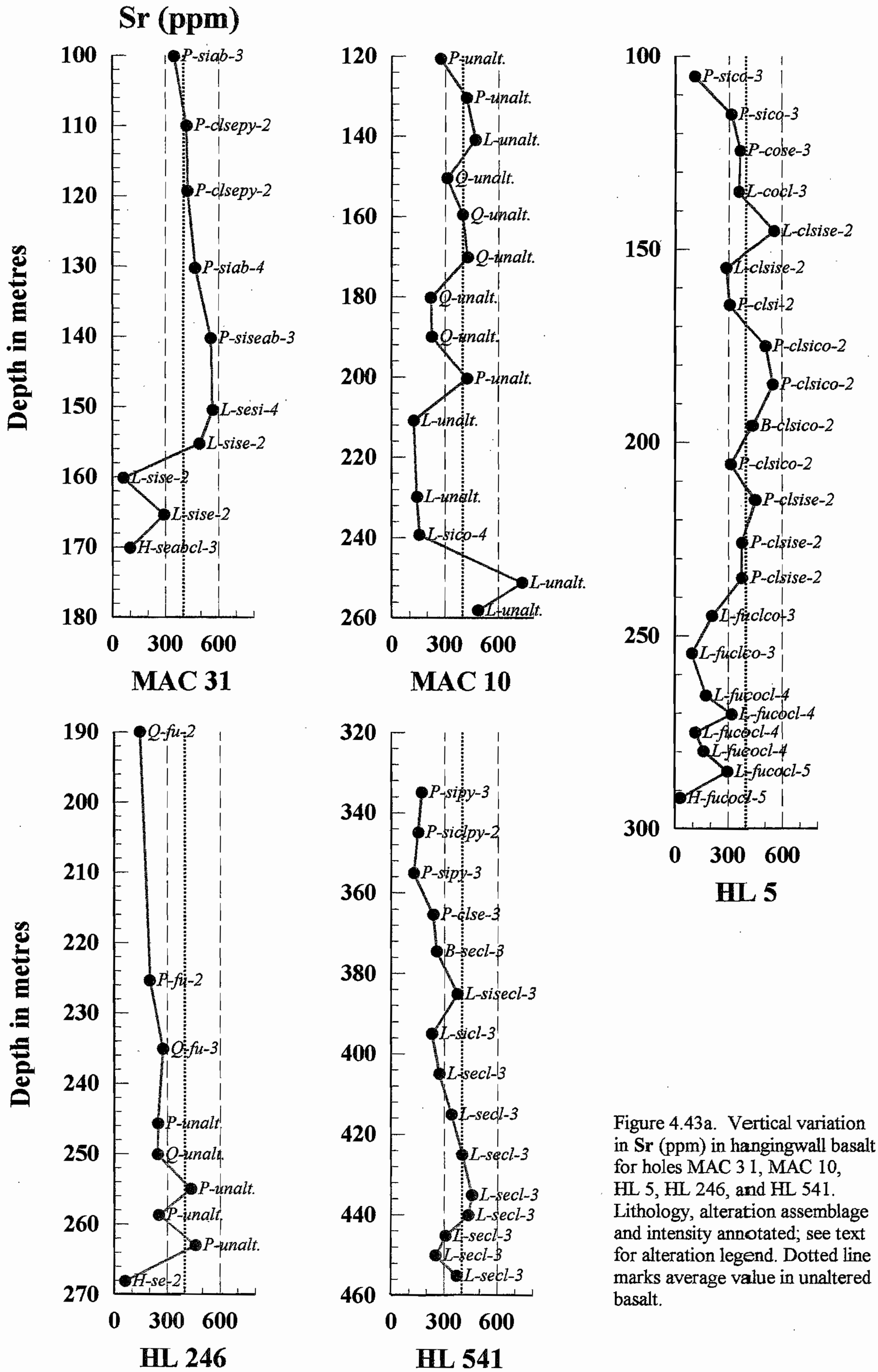


Figure 4.43a. Vertical variation in Sr (ppm) in hangingwall basalt for holes MAC 3 1, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

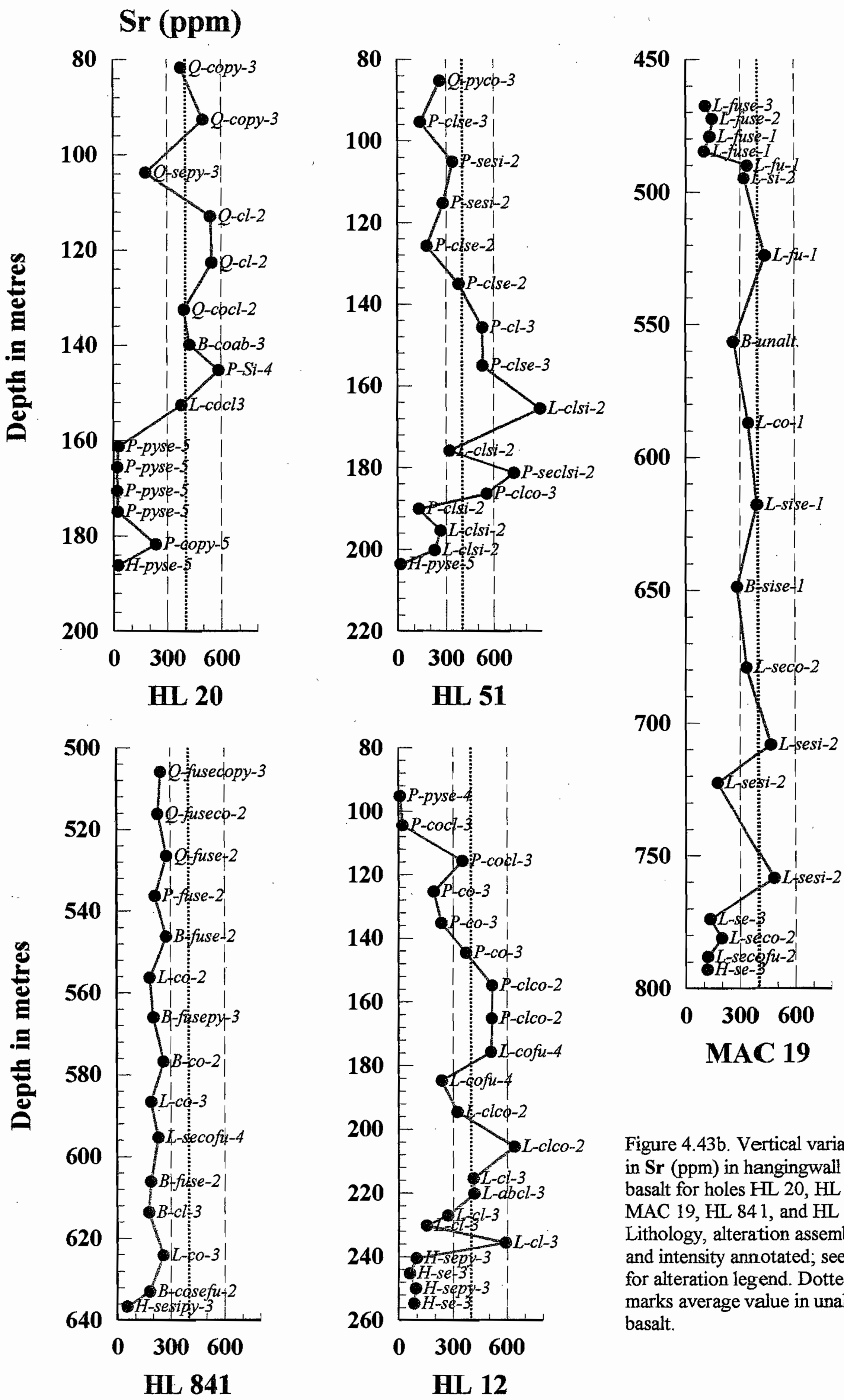


Figure 4.43b. Vertical variation in **Sr** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

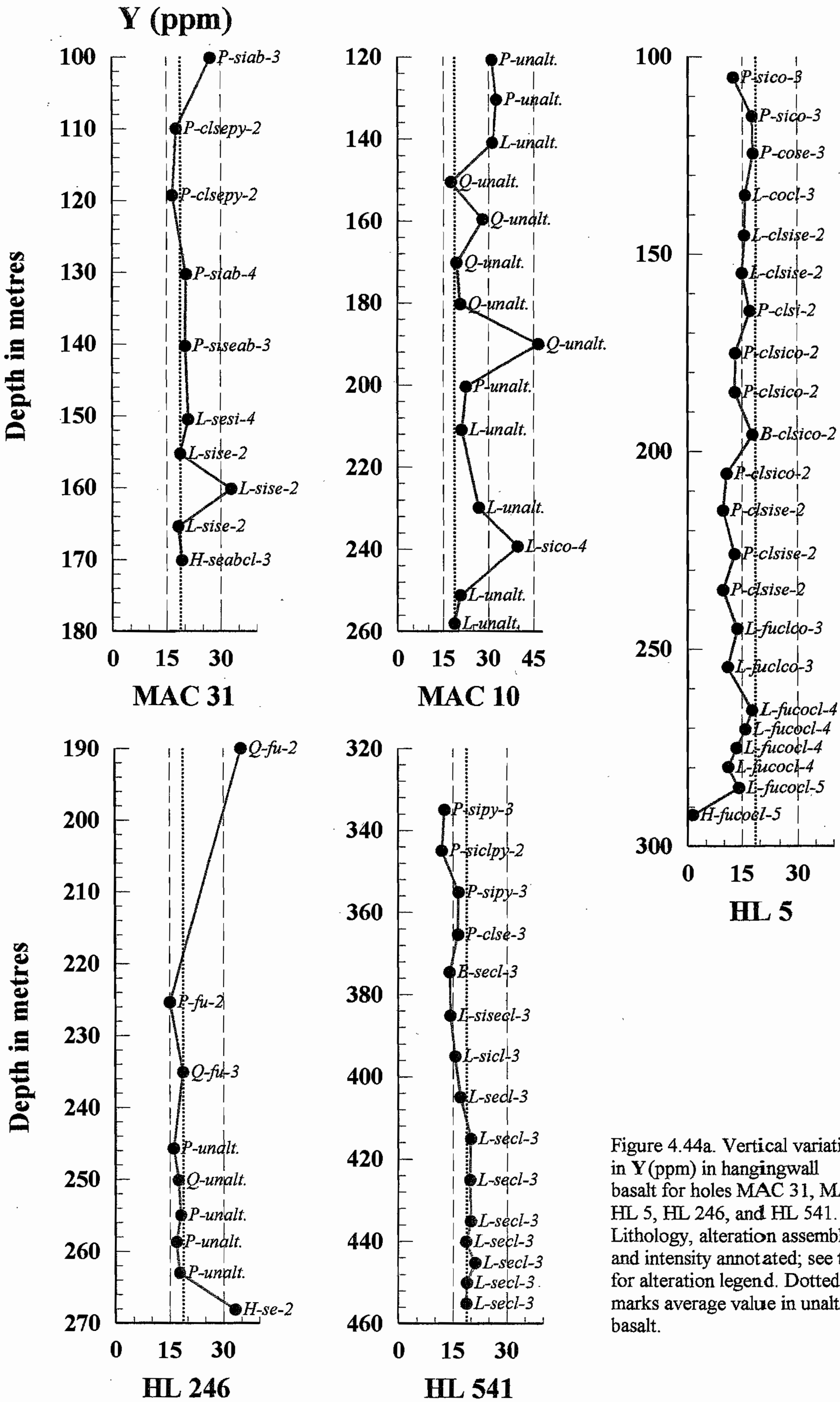


Figure 4.44a. Vertical variation in Y (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

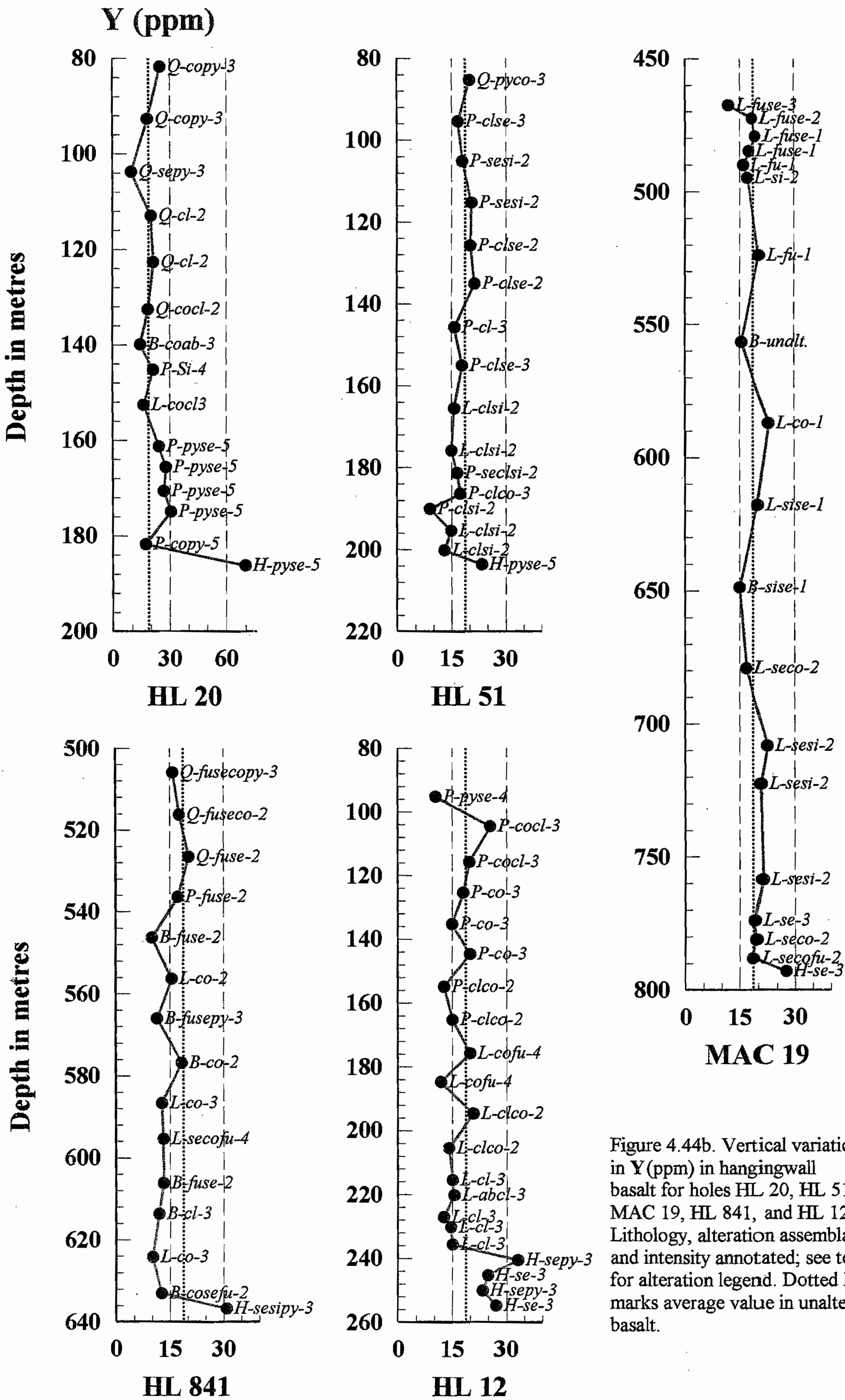


Figure 4.44b. Vertical variation in Y (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

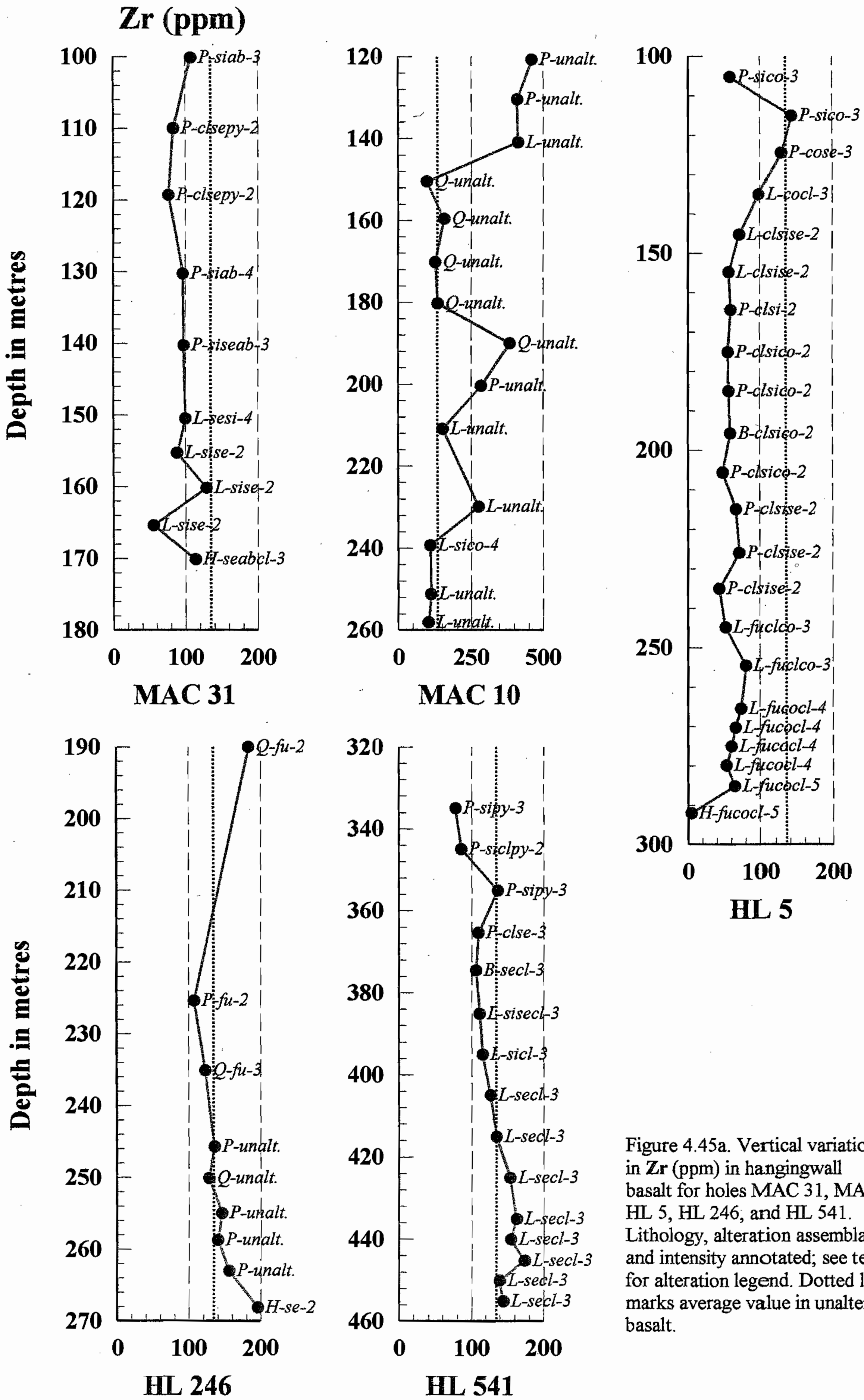


Figure 4.45a. Vertical variation in **Zr** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

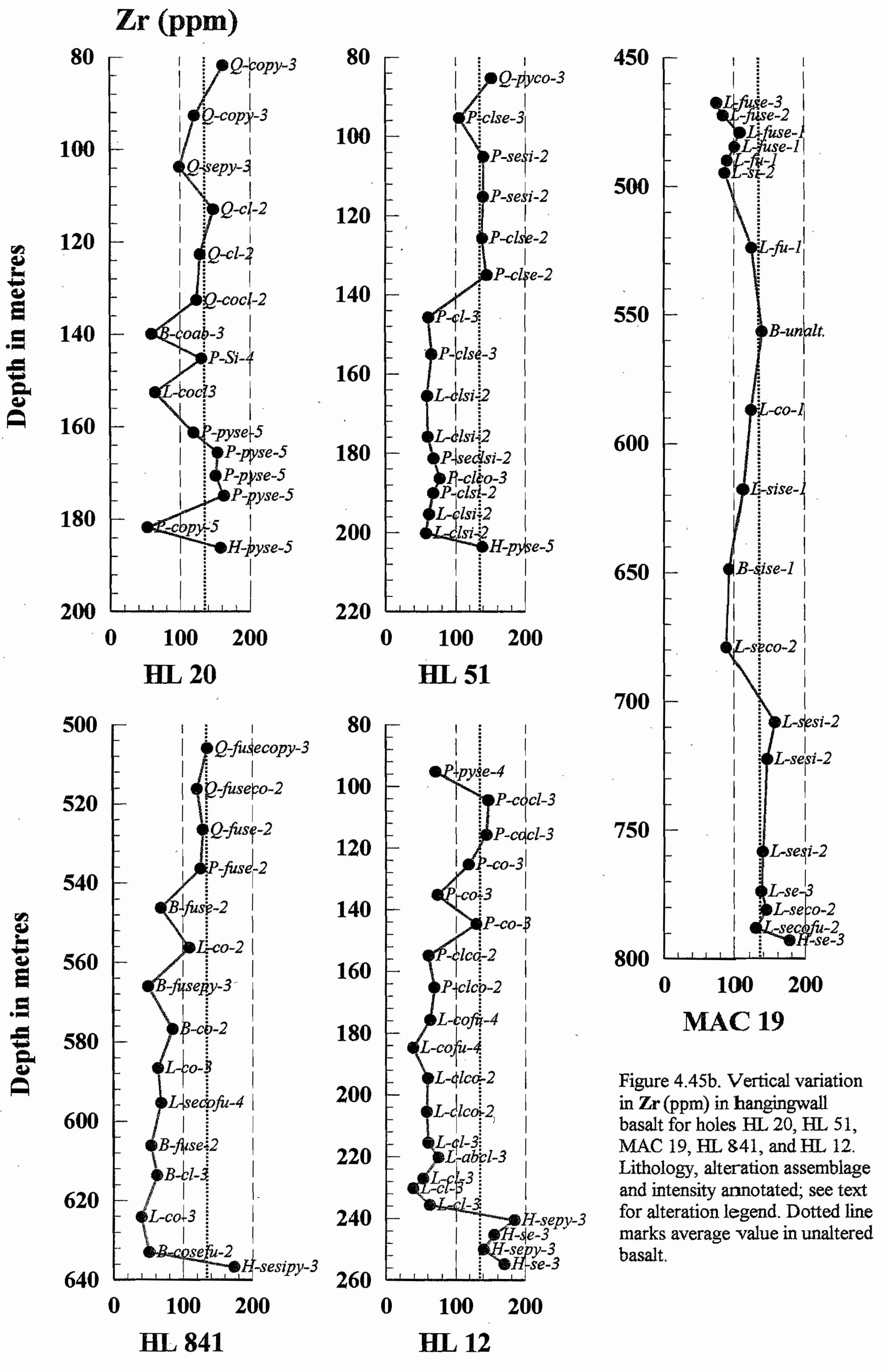


Figure 4.45b. Vertical variation in **Zr** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

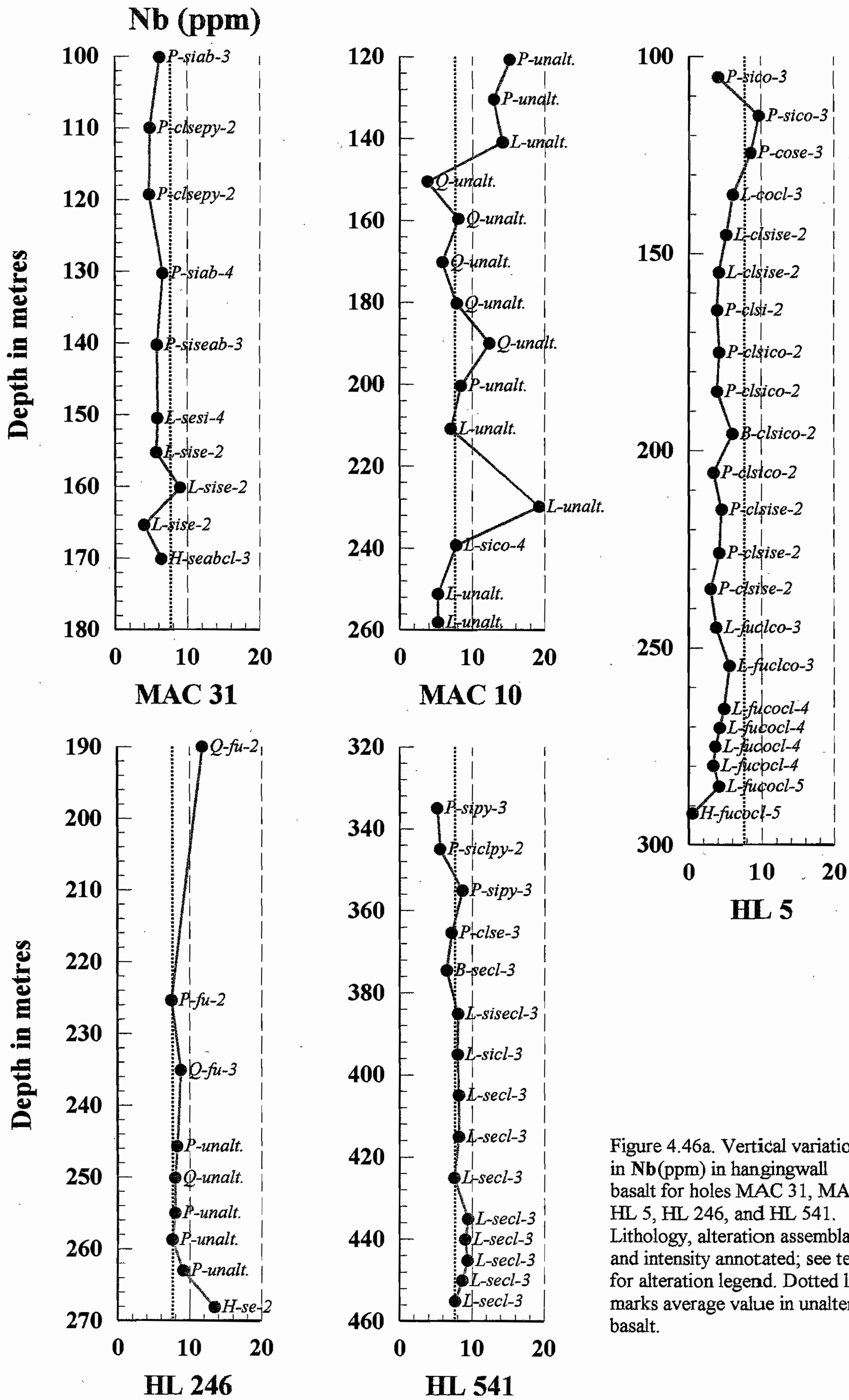


Figure 4.46a. Vertical variation in Nb (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

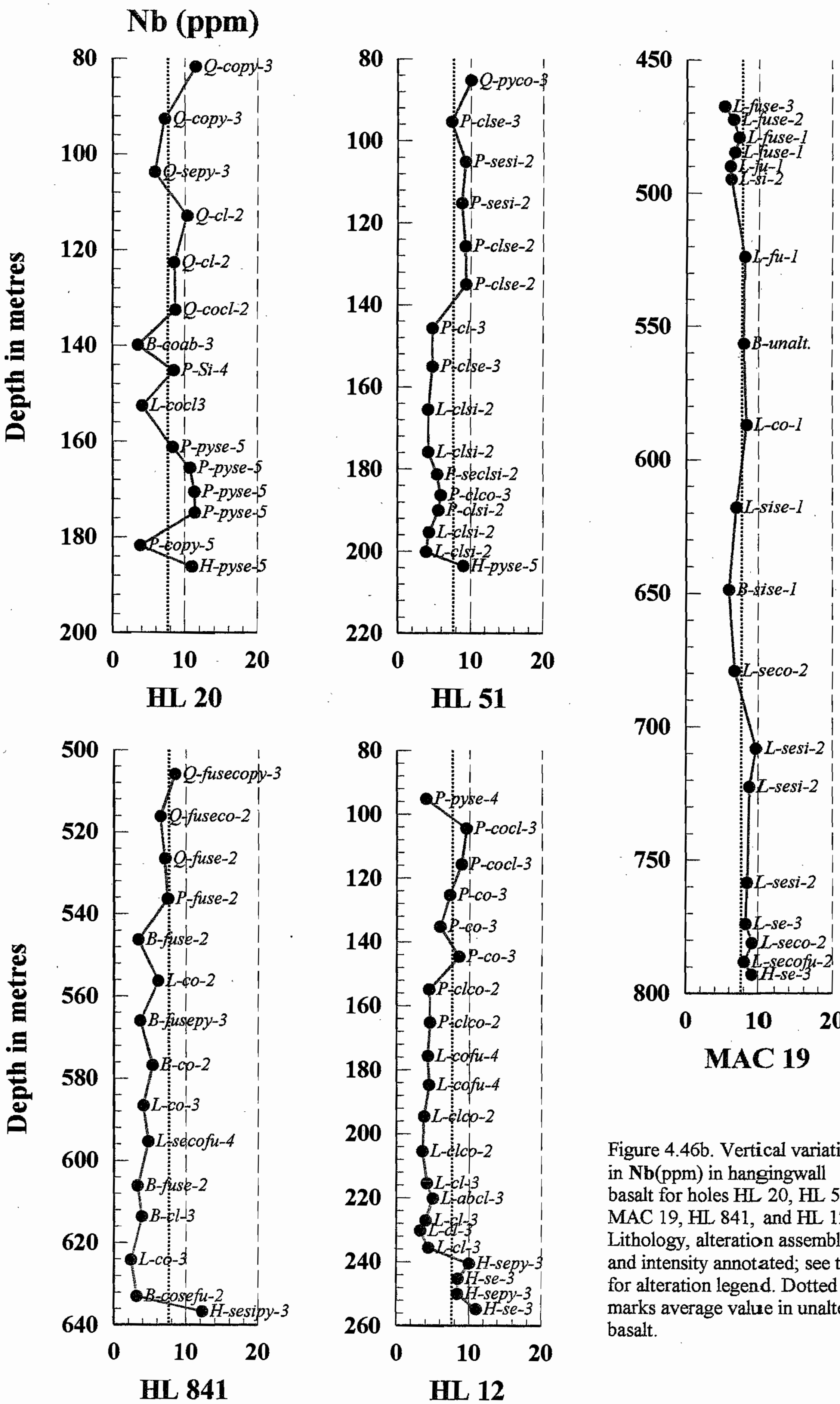


Figure 4.46b. Vertical variation in Nb(ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

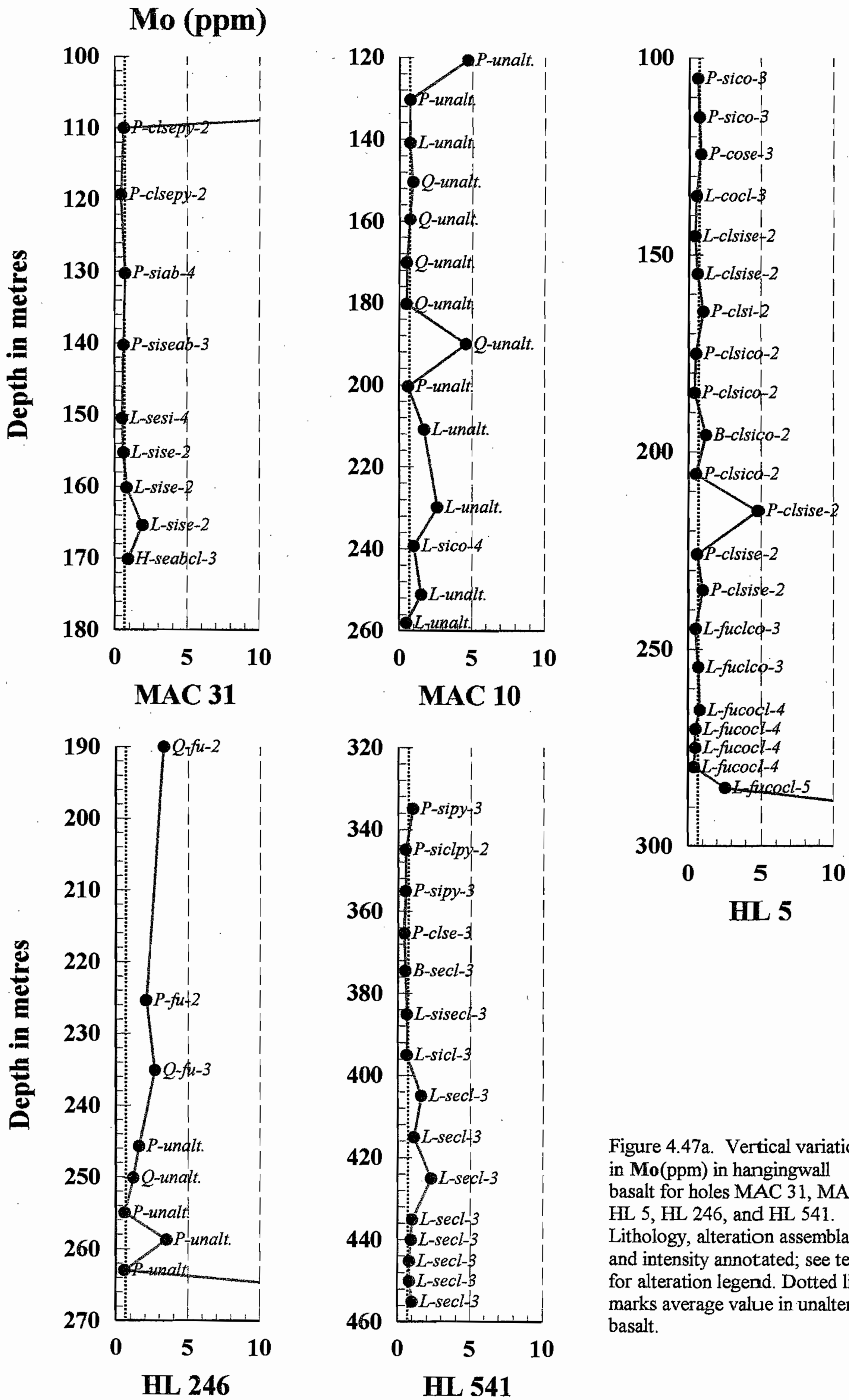


Figure 4.47a. Vertical variation in **Mo**(ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

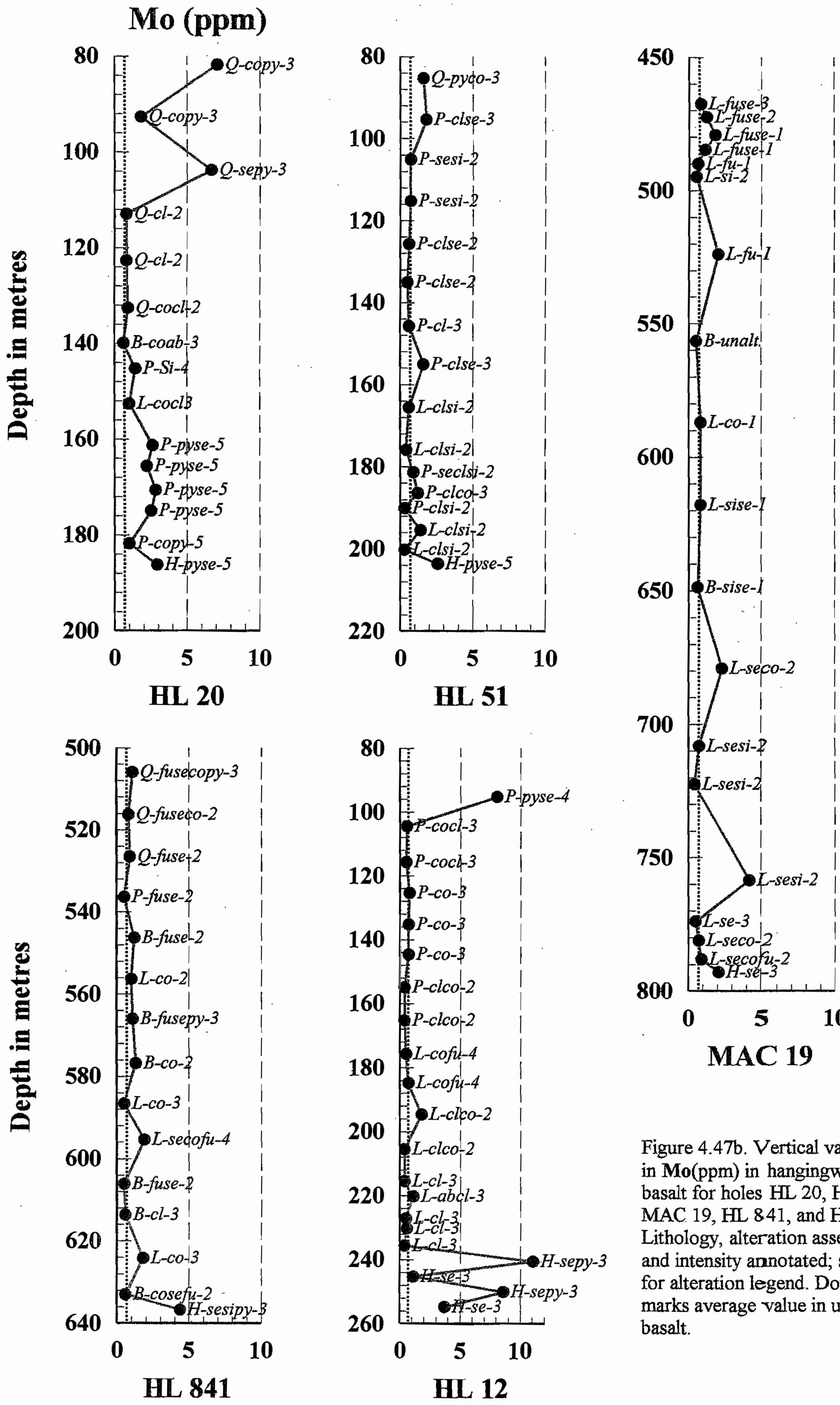


Figure 4.47b. Vertical variation in Mo(ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

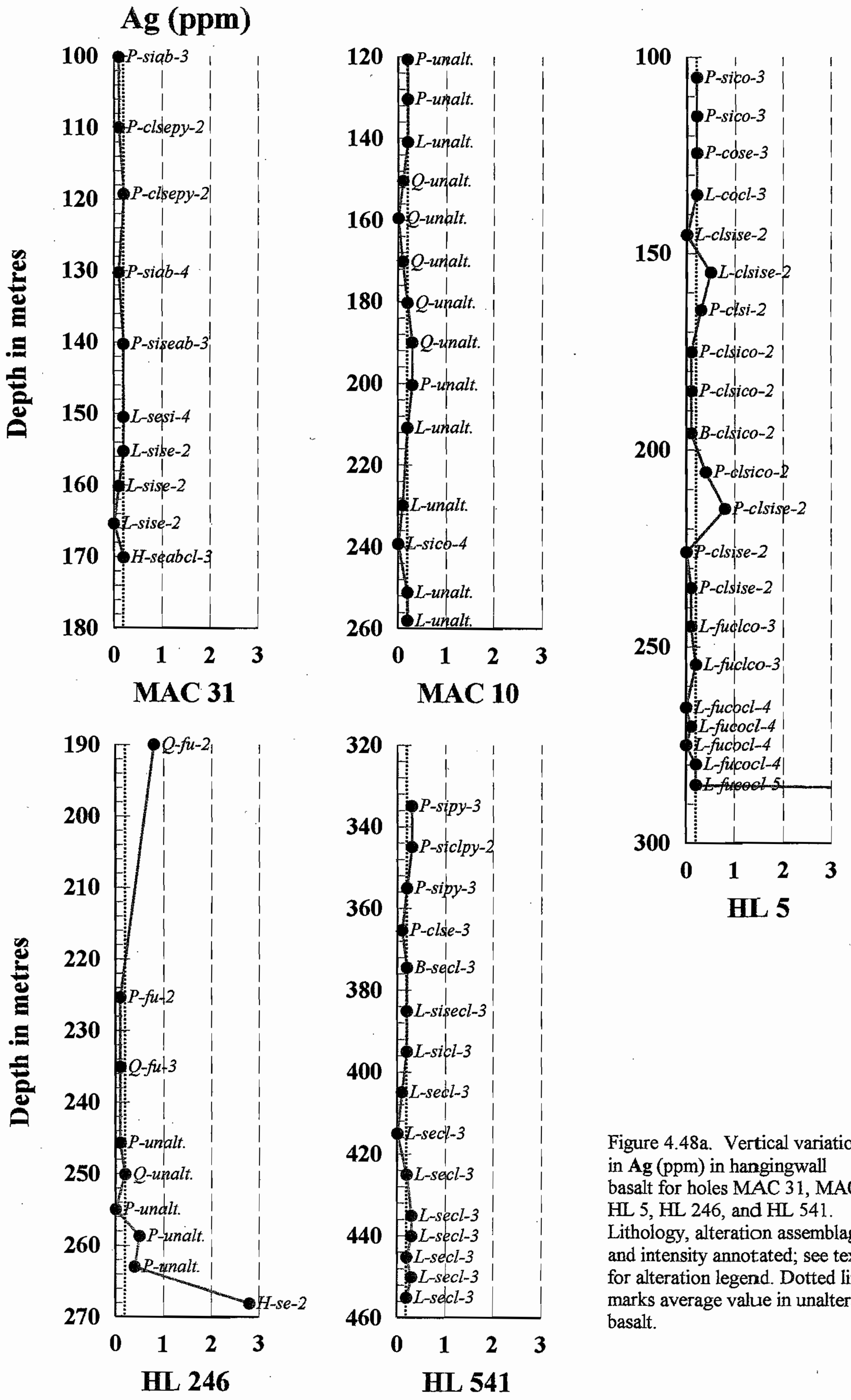


Figure 4.48a. Vertical variation in **Ag** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

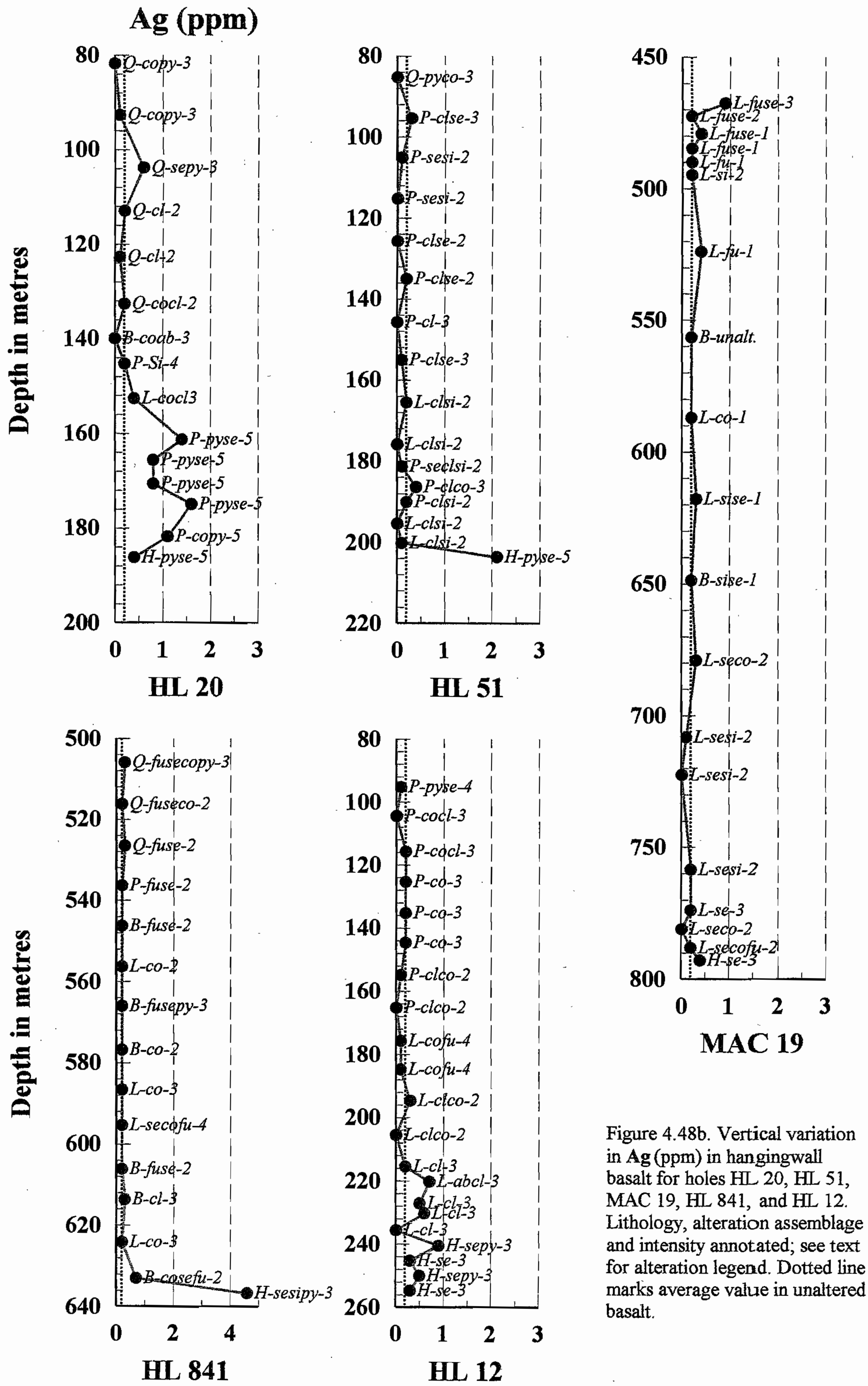


Figure 4.48b. Vertical variation in **Ag** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

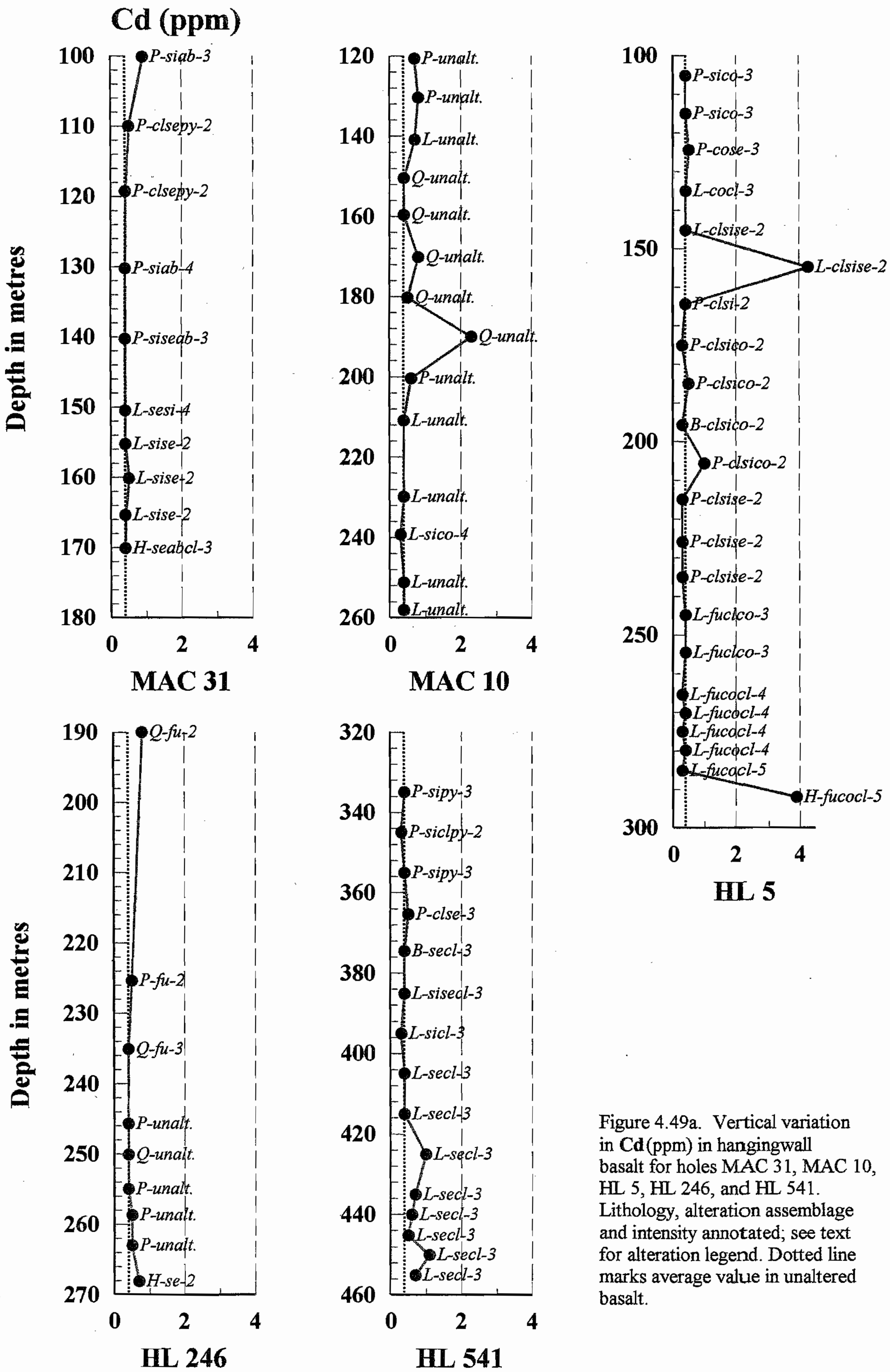


Figure 4.49a. Vertical variation in **Cd** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

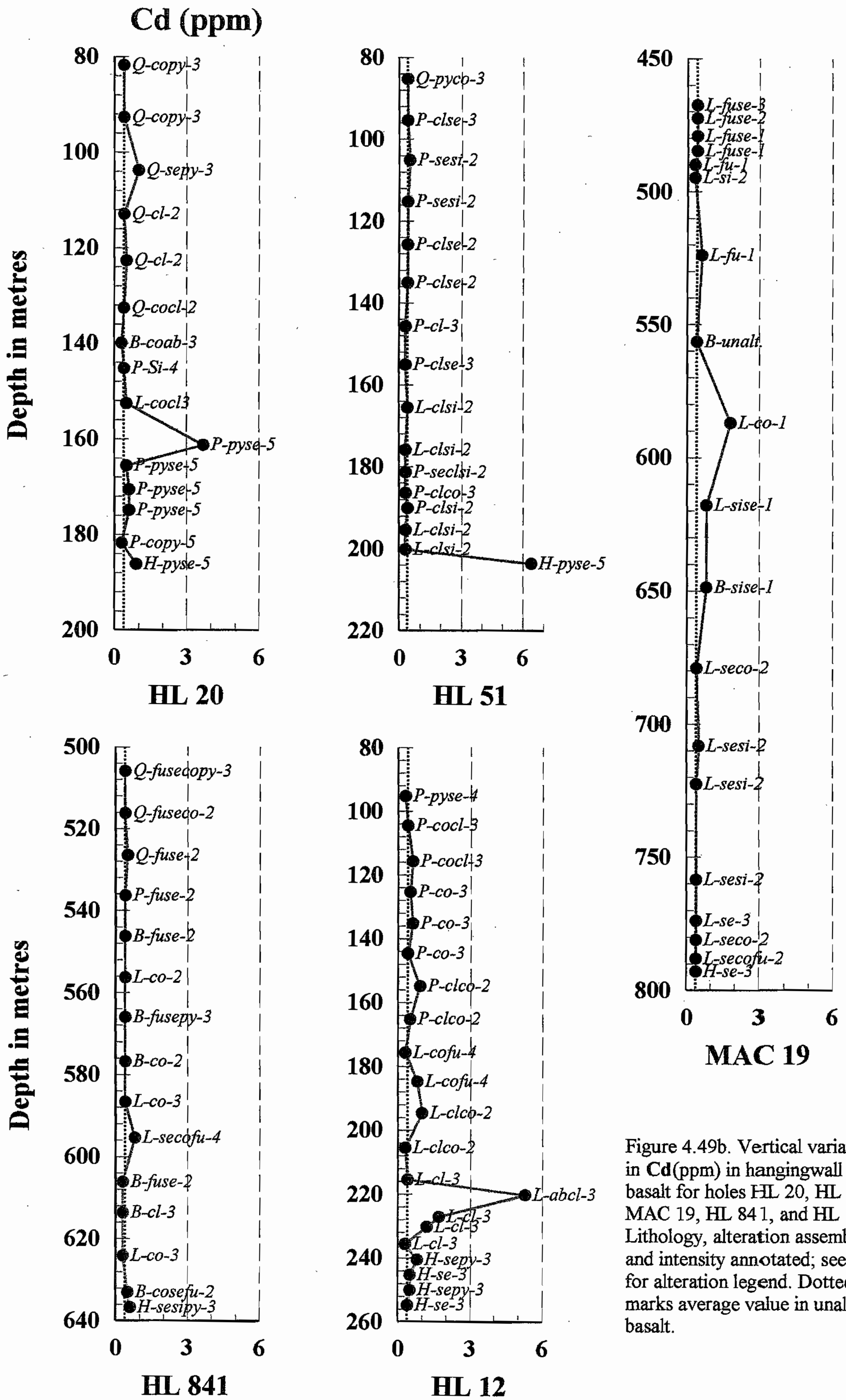


Figure 4.49b. Vertical variation in Cd(ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

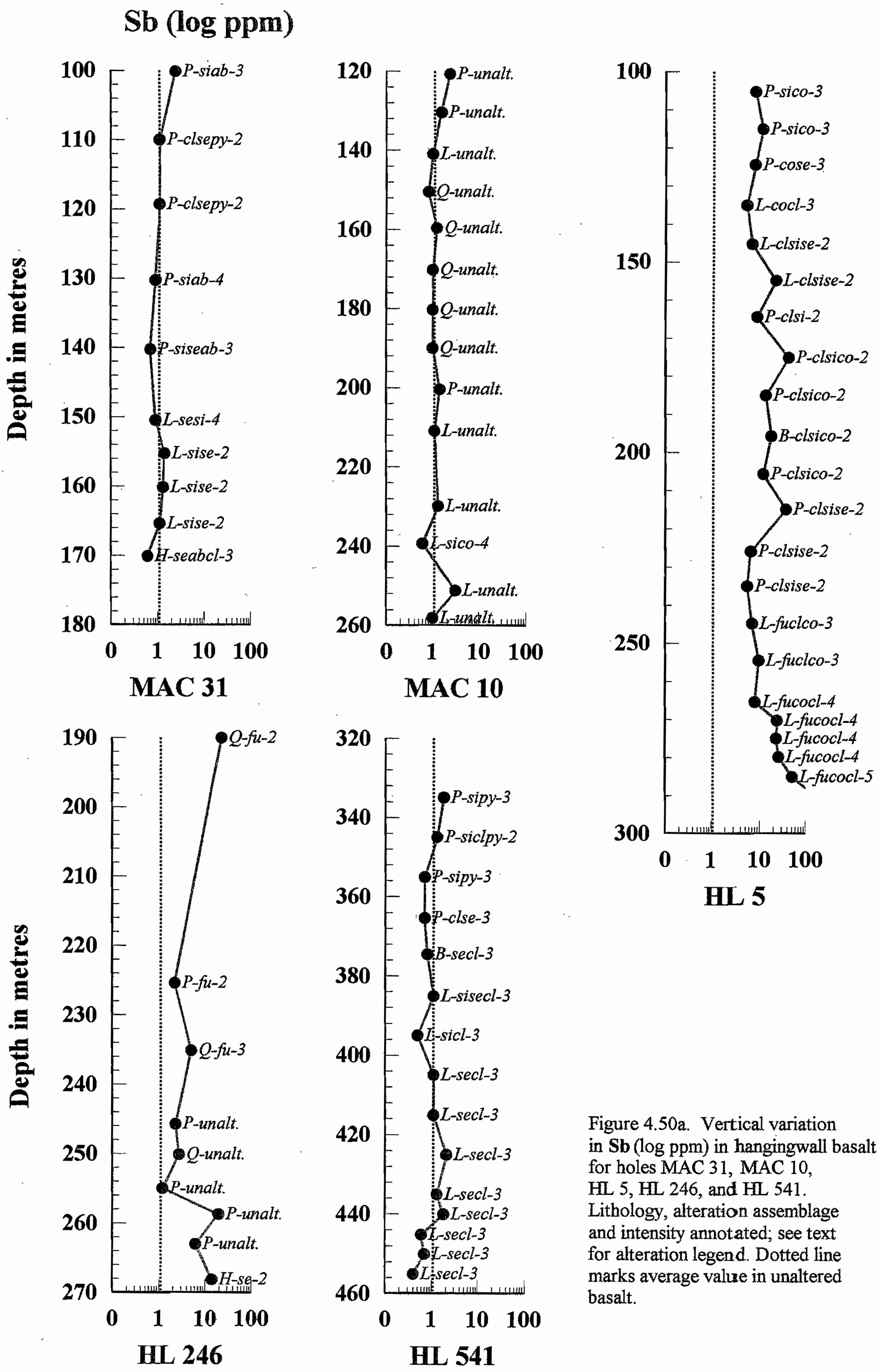


Figure 4.50a. Vertical variation in **Sb** (log ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

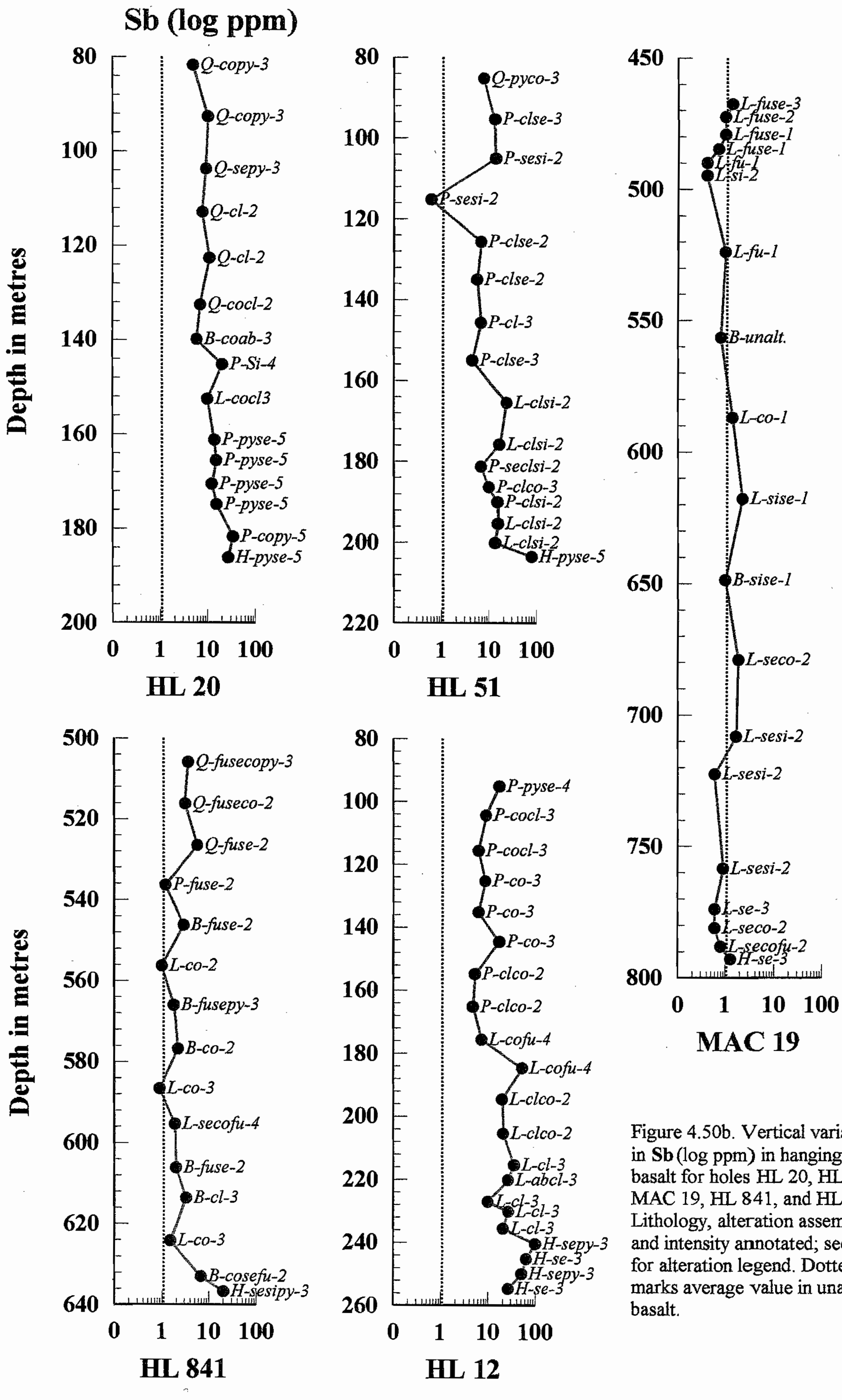


Figure 4.50b. Vertical variation in **Sb** (log ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

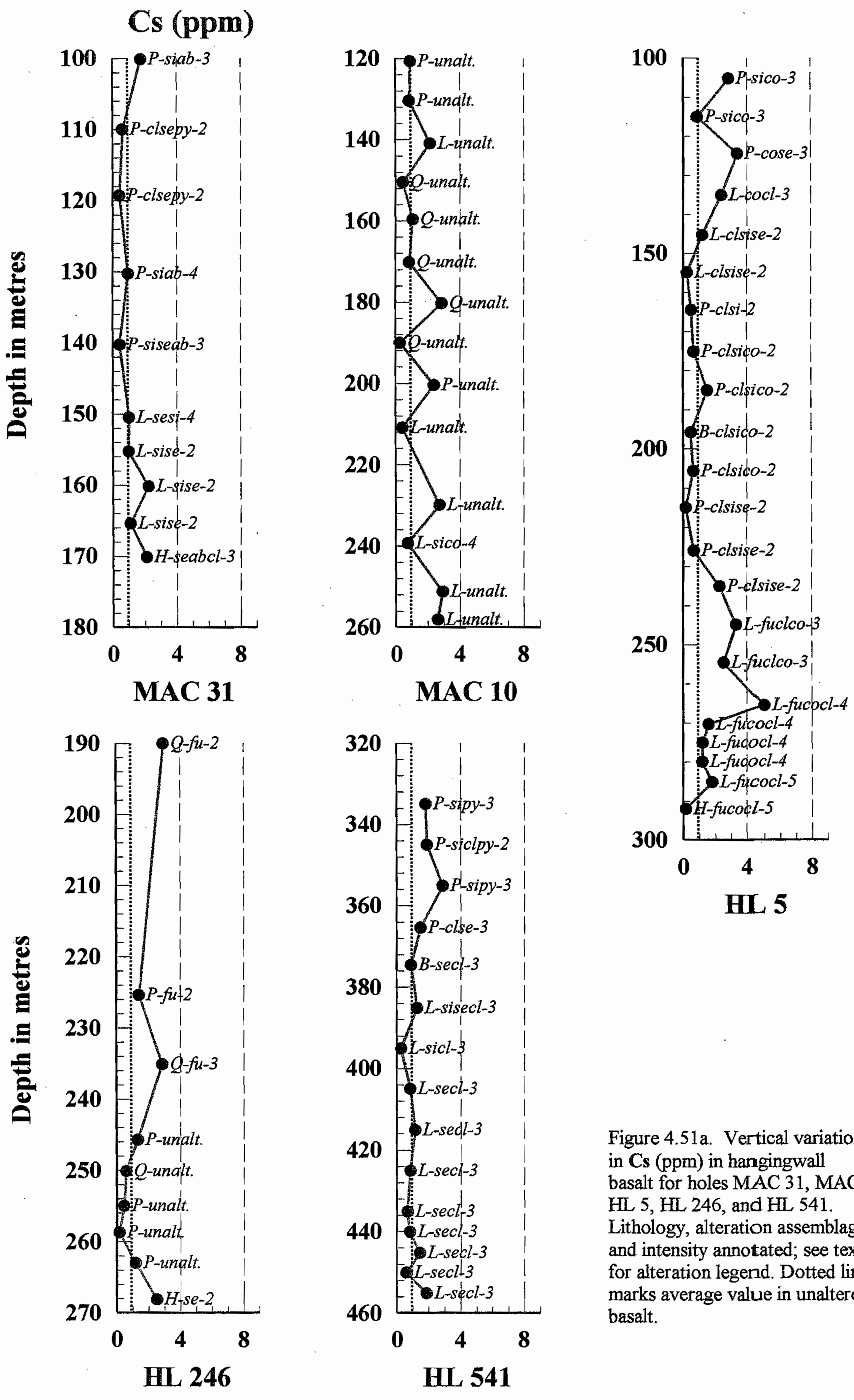
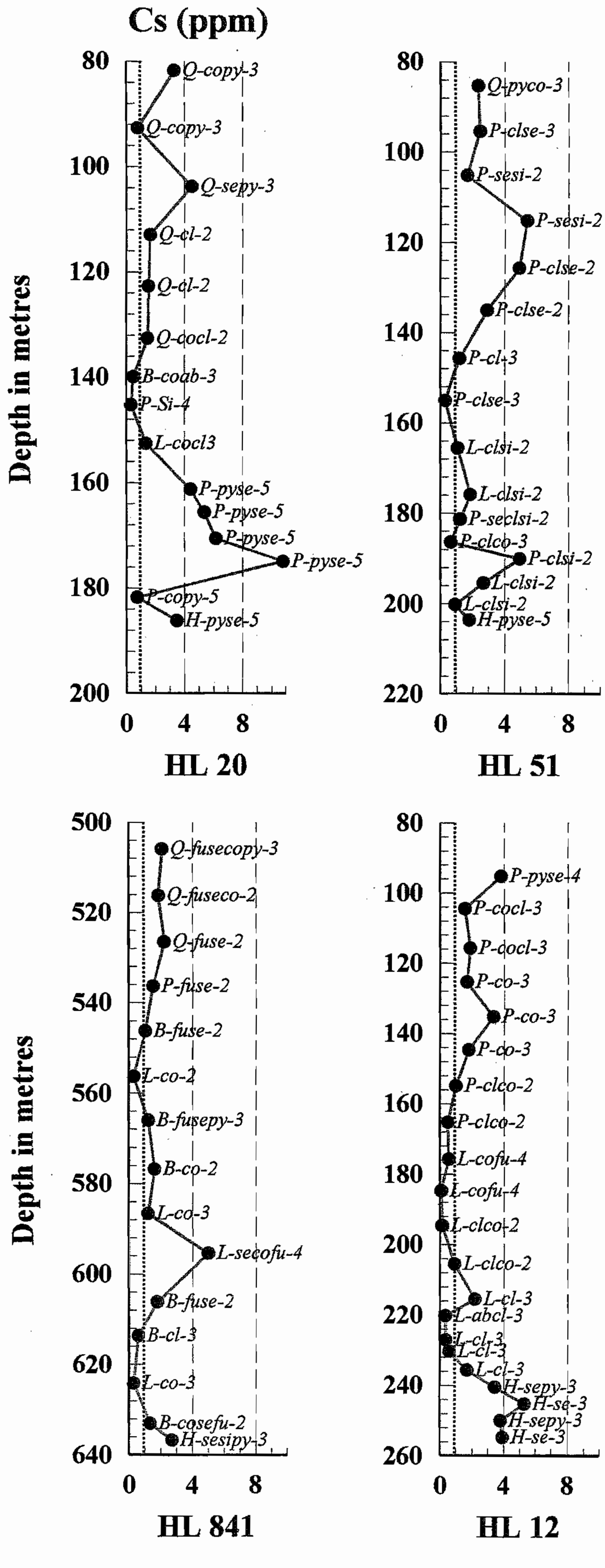


Figure 4.51a. Vertical variation in Cs (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.



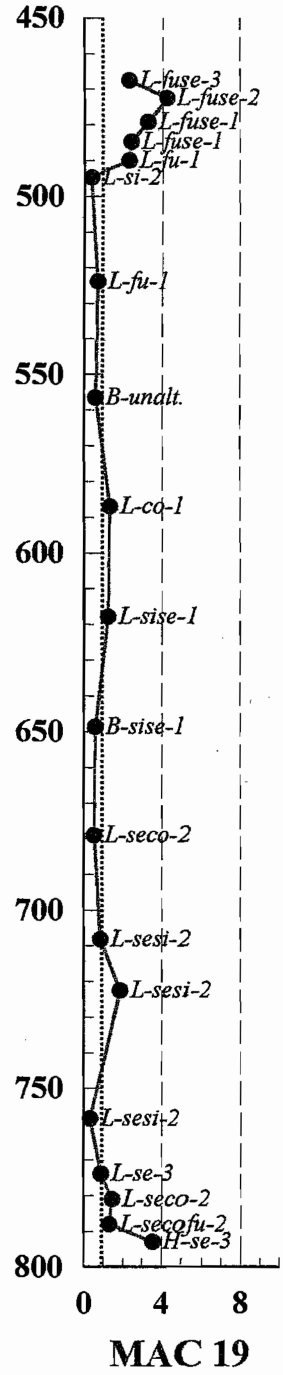


Figure 4.51b. Vertical variation in **Cs** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

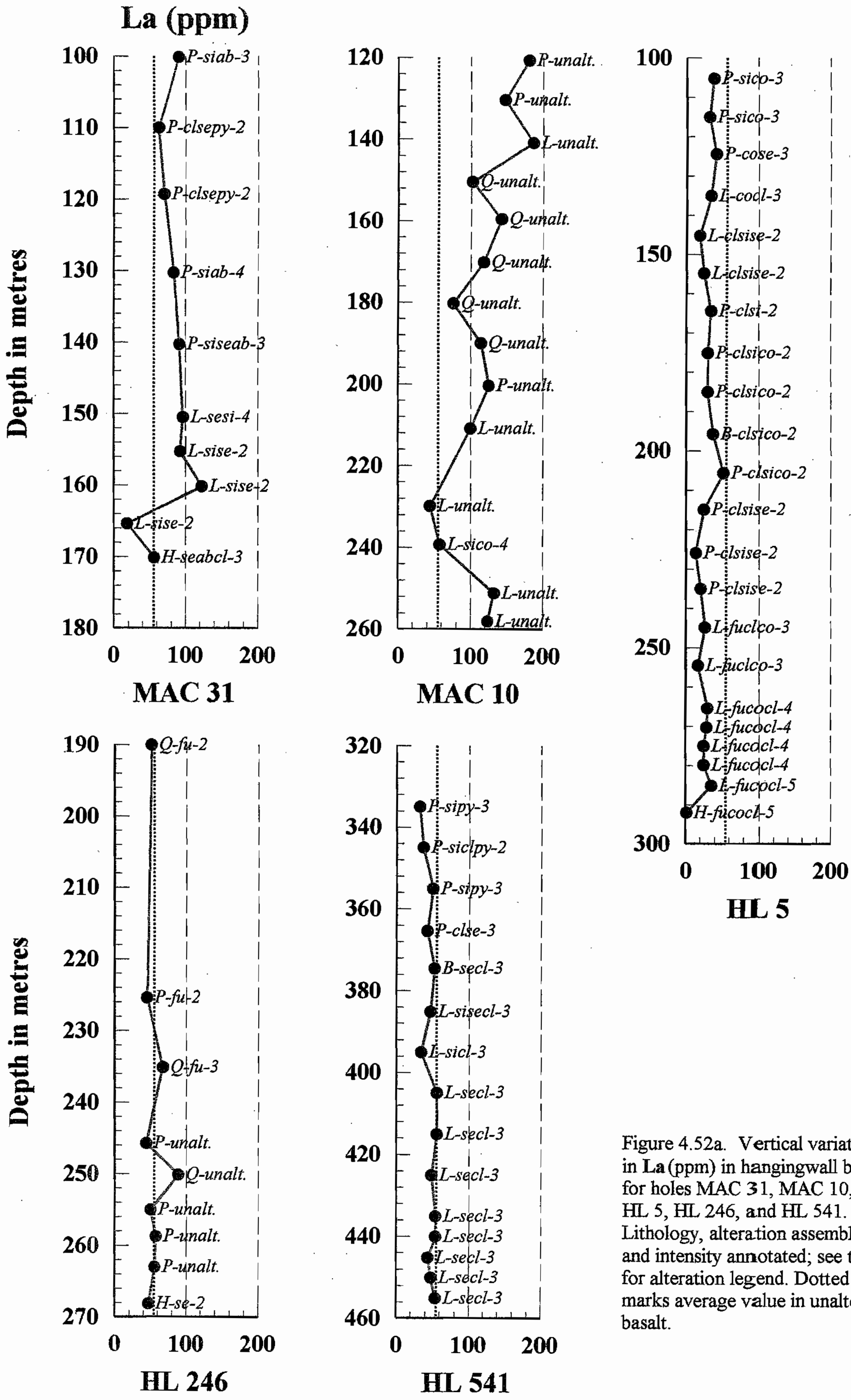


Figure 4.52a. Vertical variation in La (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

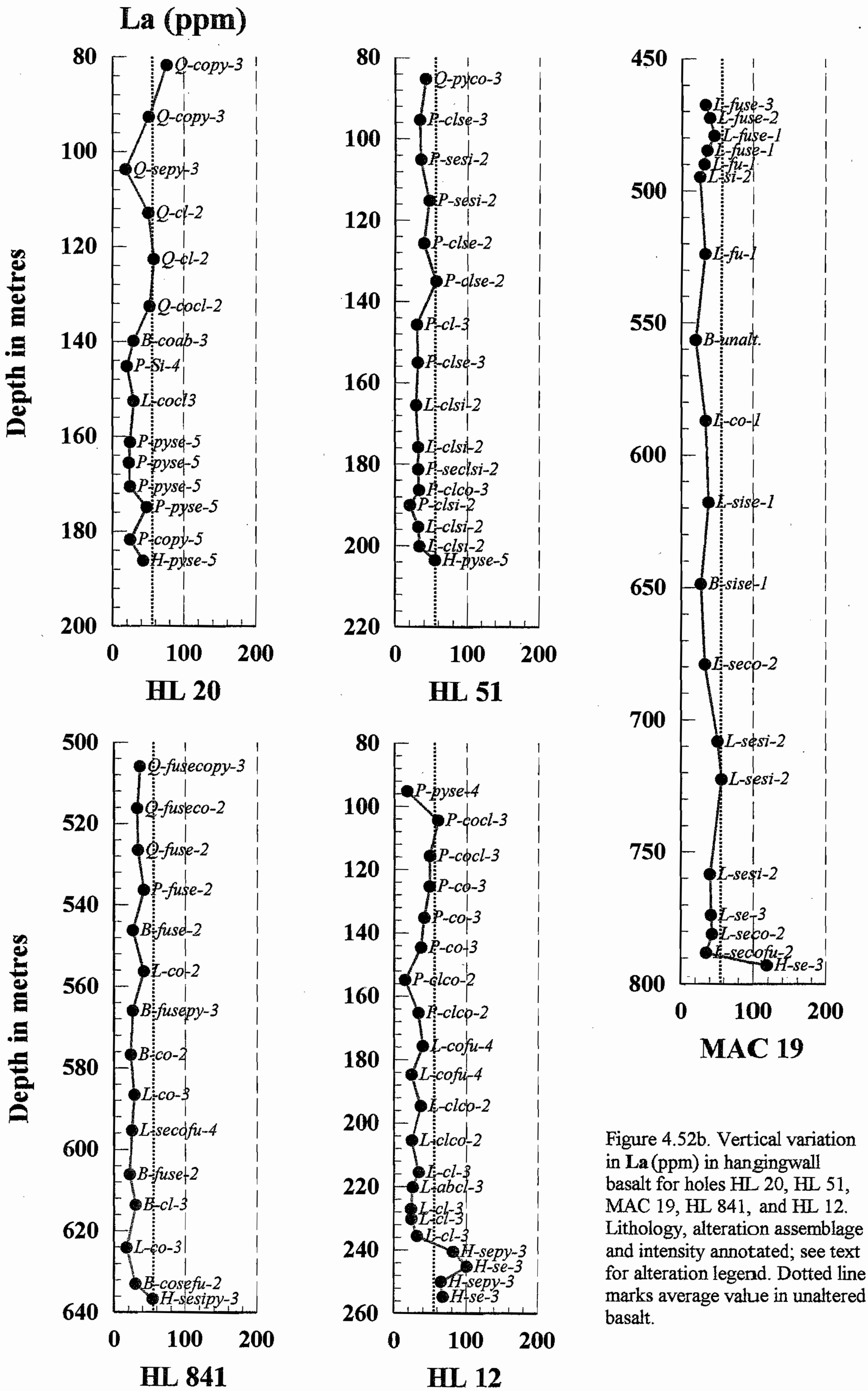


Figure 4.52b. Vertical variation in La (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

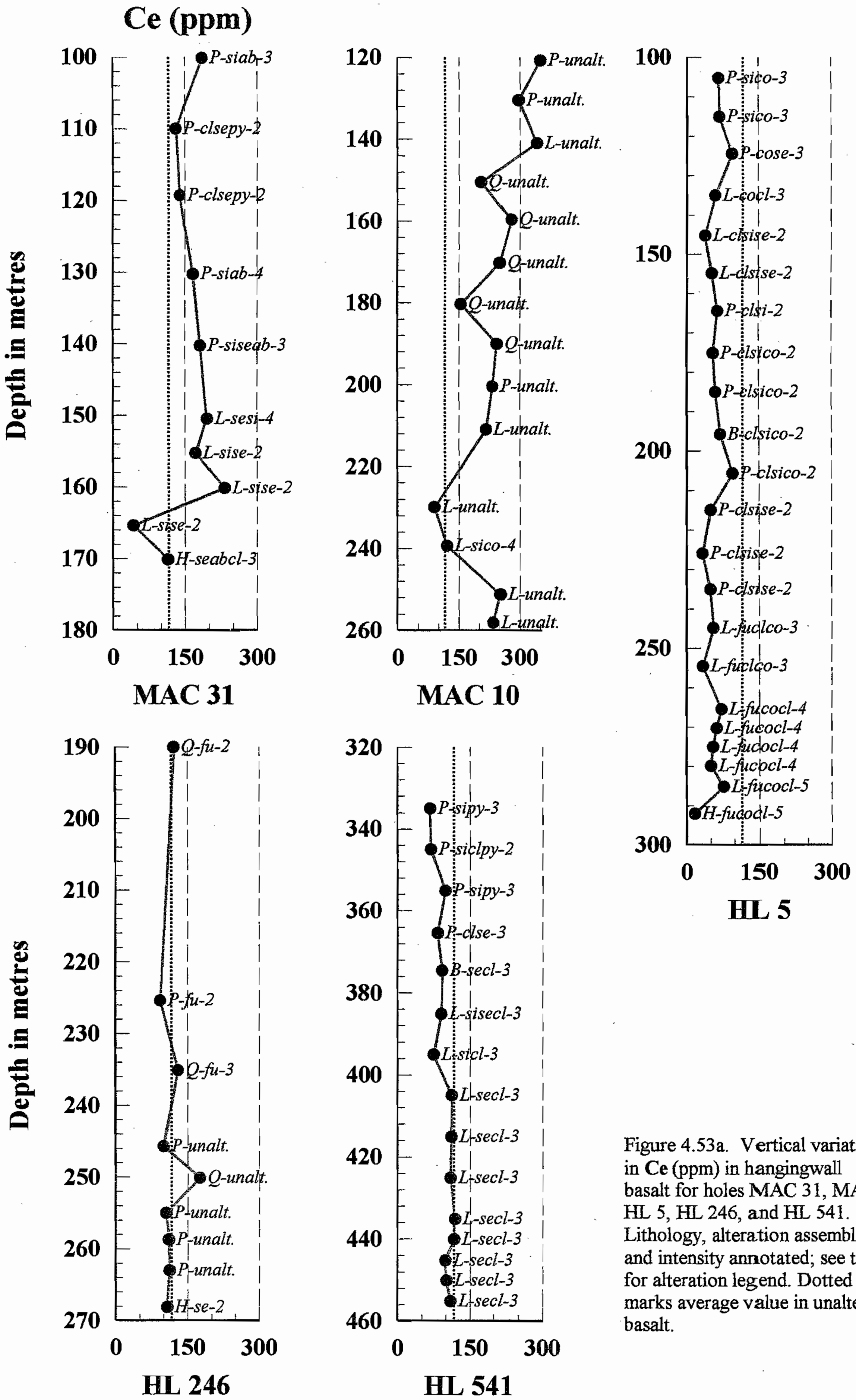


Figure 4.53a. Vertical variation in Ce (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

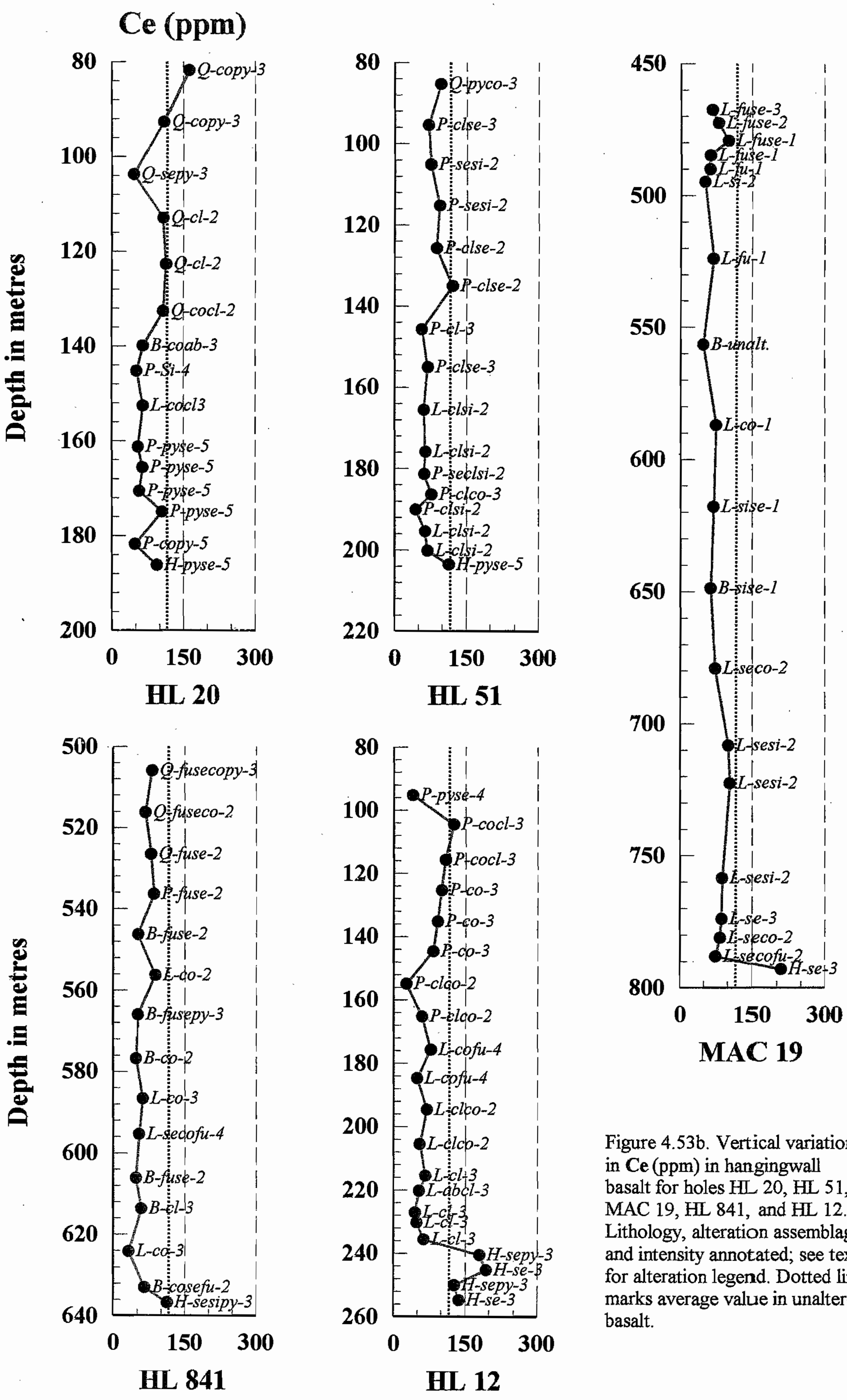


Figure 4.53b. Vertical variation in Ce (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

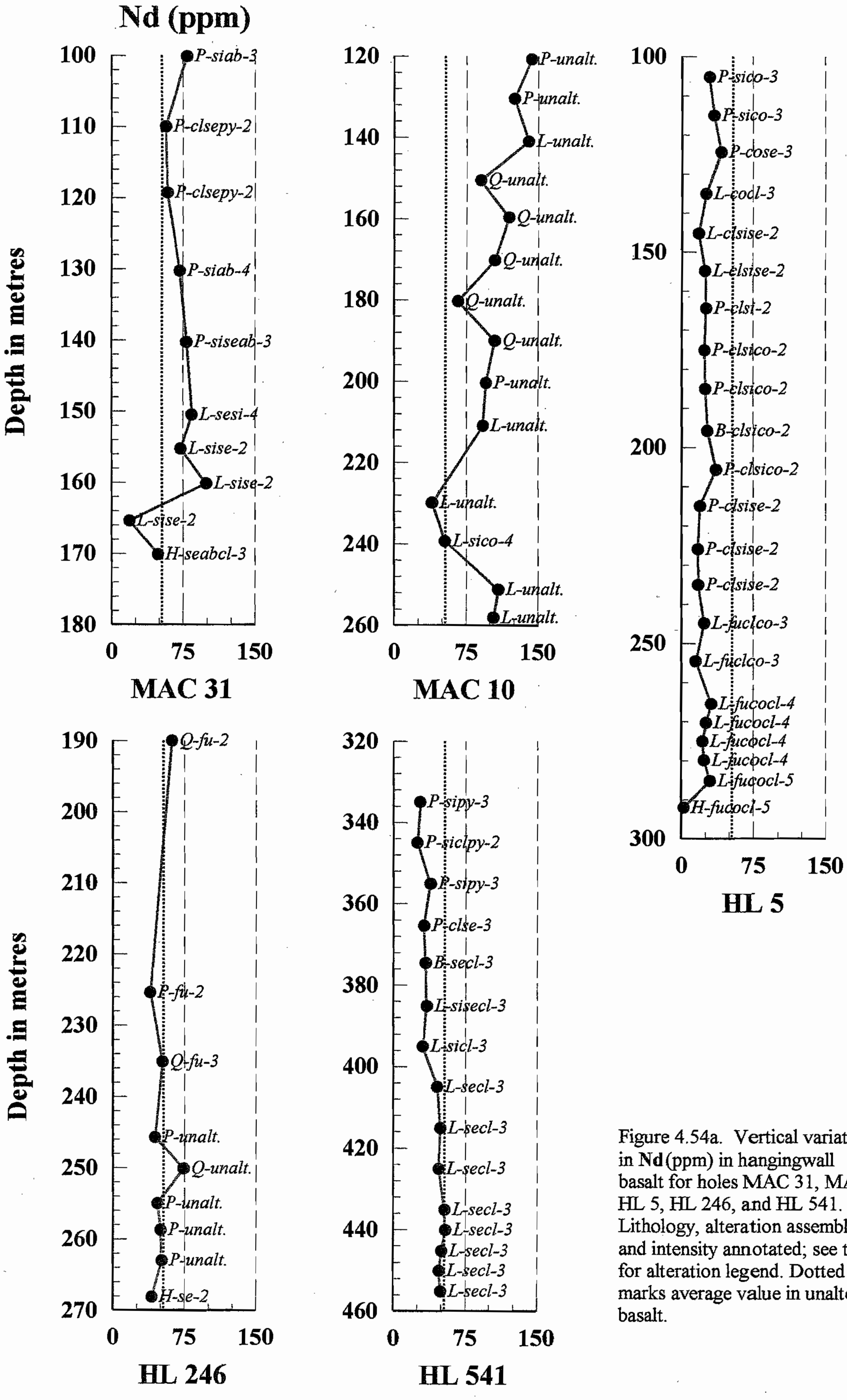


Figure 4.54a. Vertical variation in **Nd** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

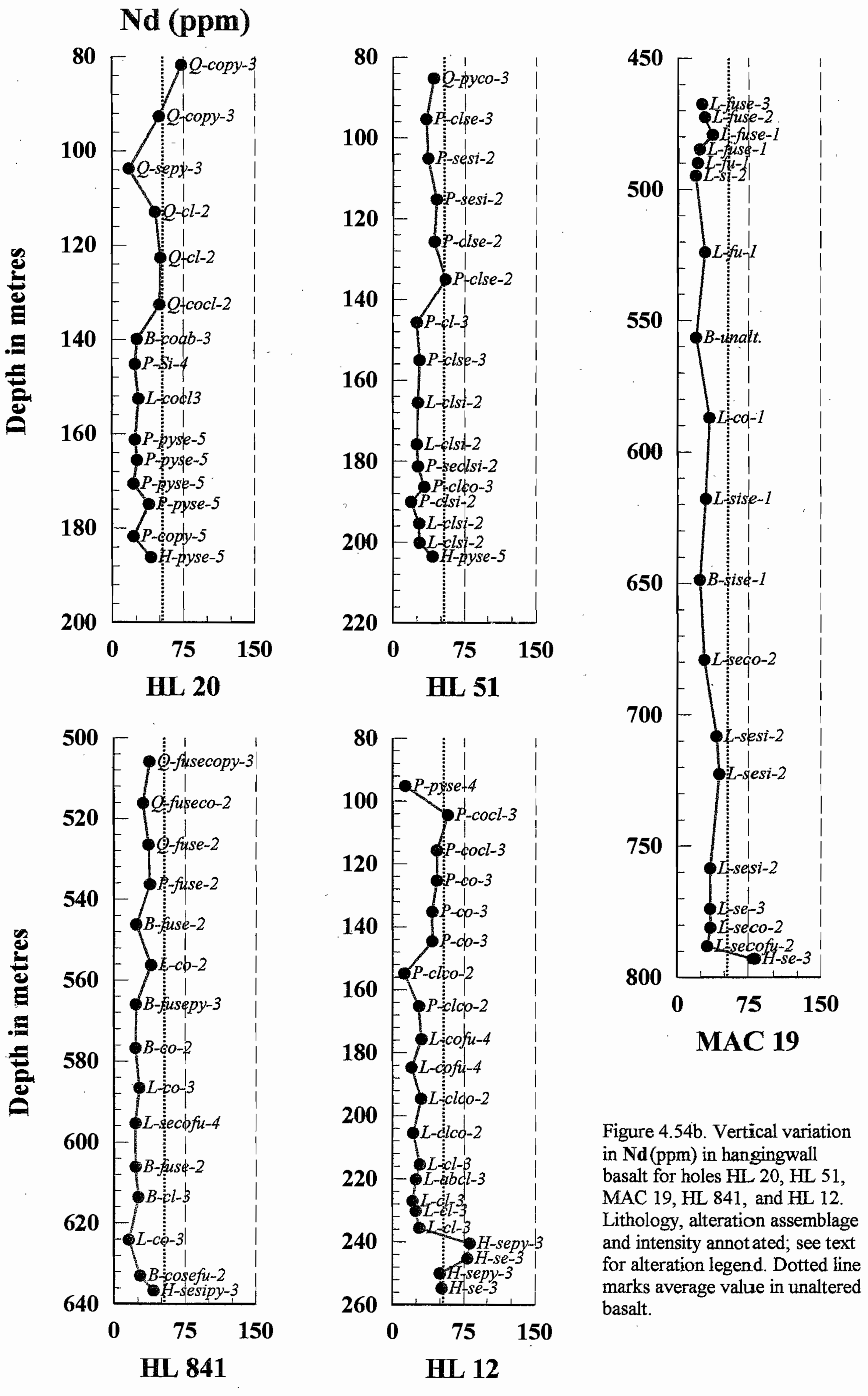


Figure 4.54b. Vertical variation in **Nd** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

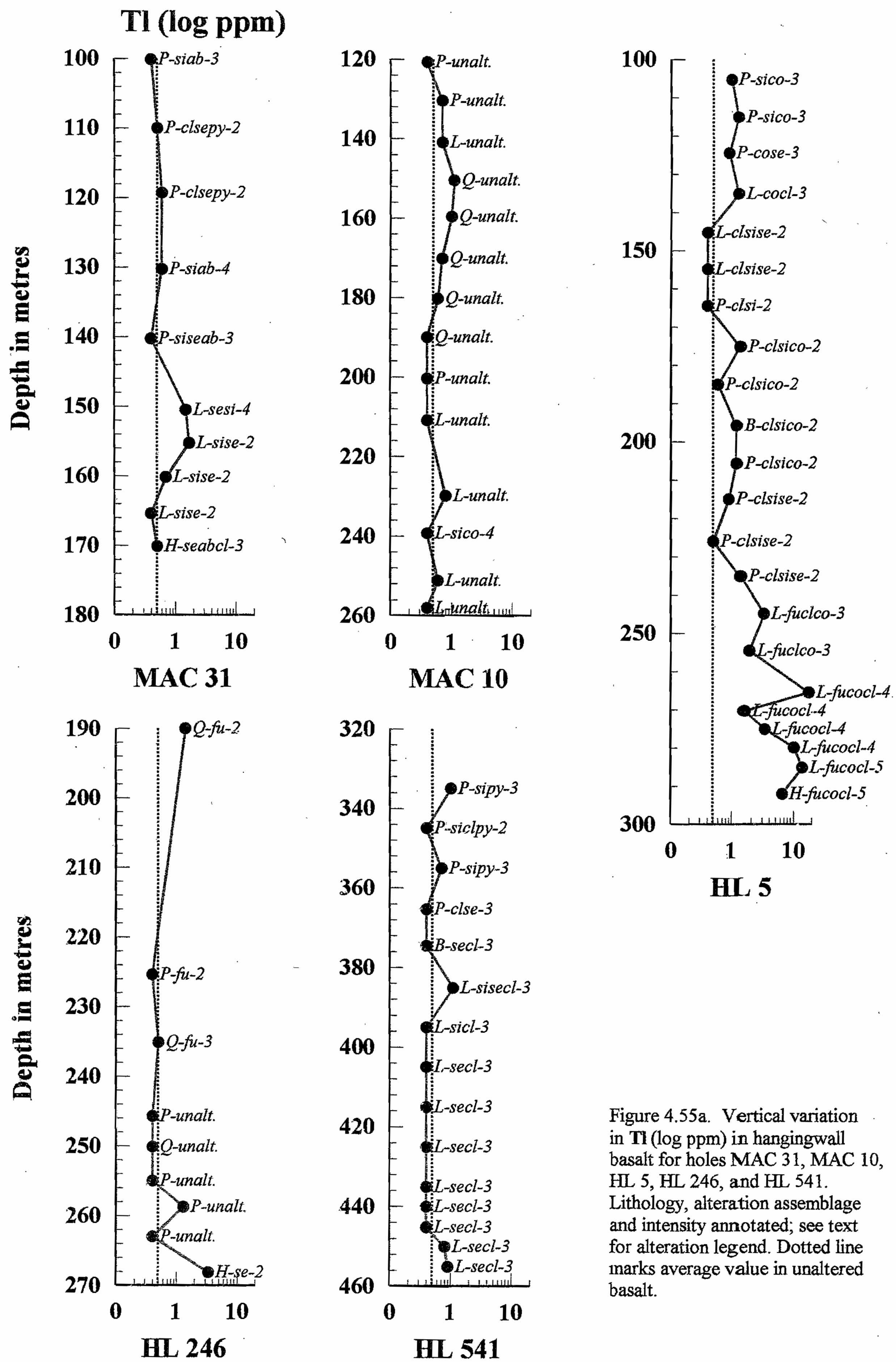


Figure 4.55a. Vertical variation in Tl (log ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

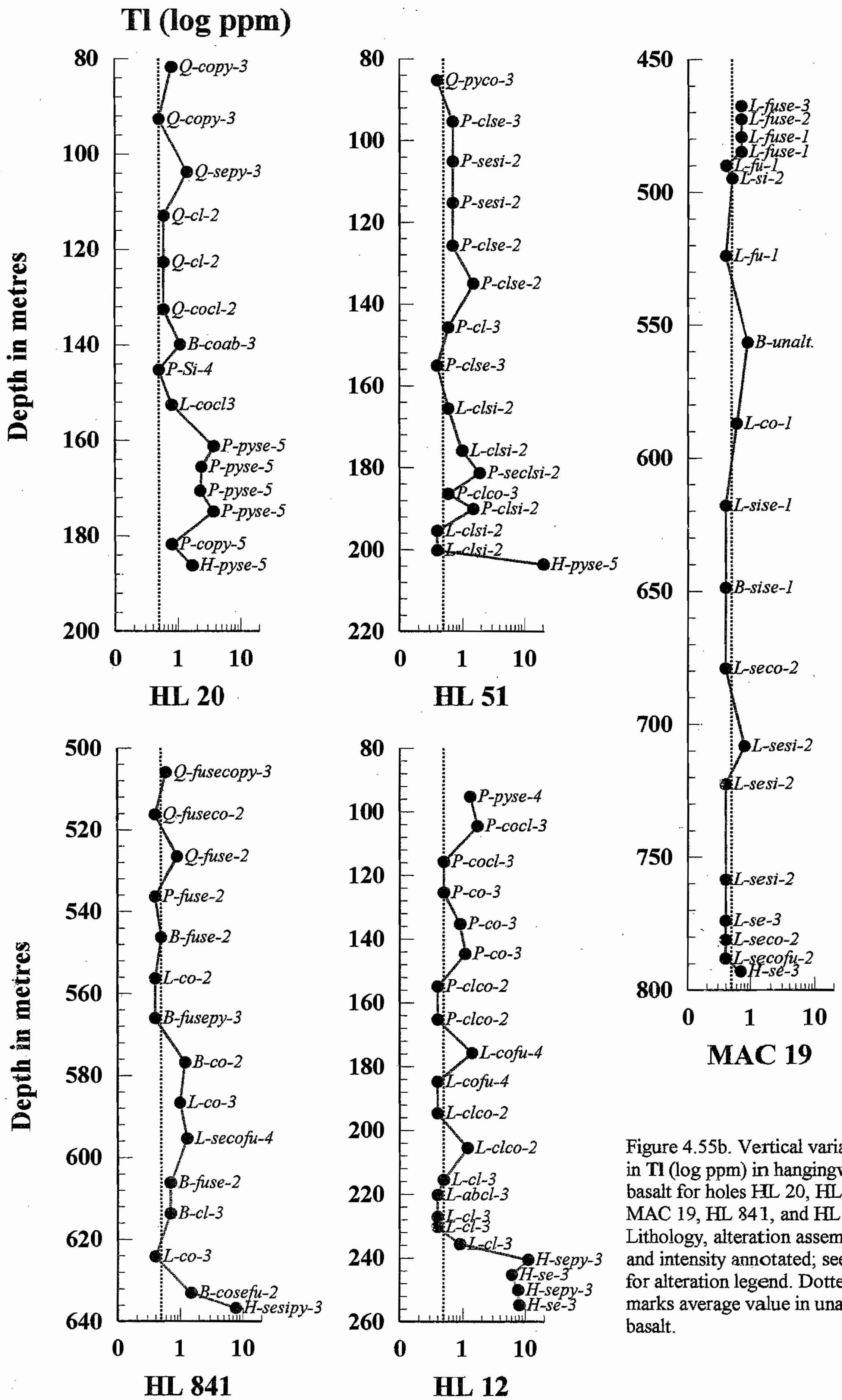


Figure 4.55b. Vertical variation in Tl (log ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

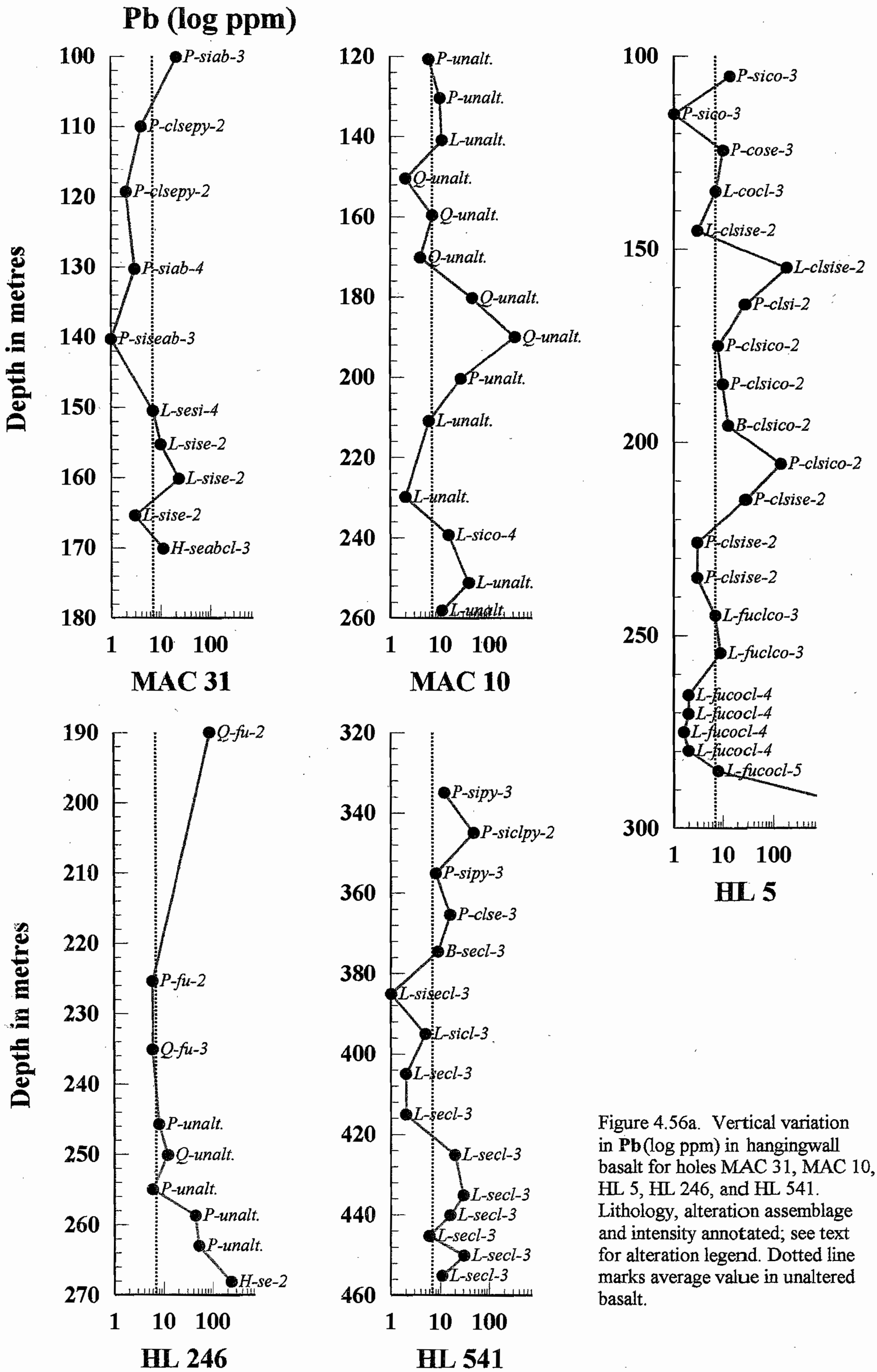


Figure 4.56a. Vertical variation in **Pb** (log ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

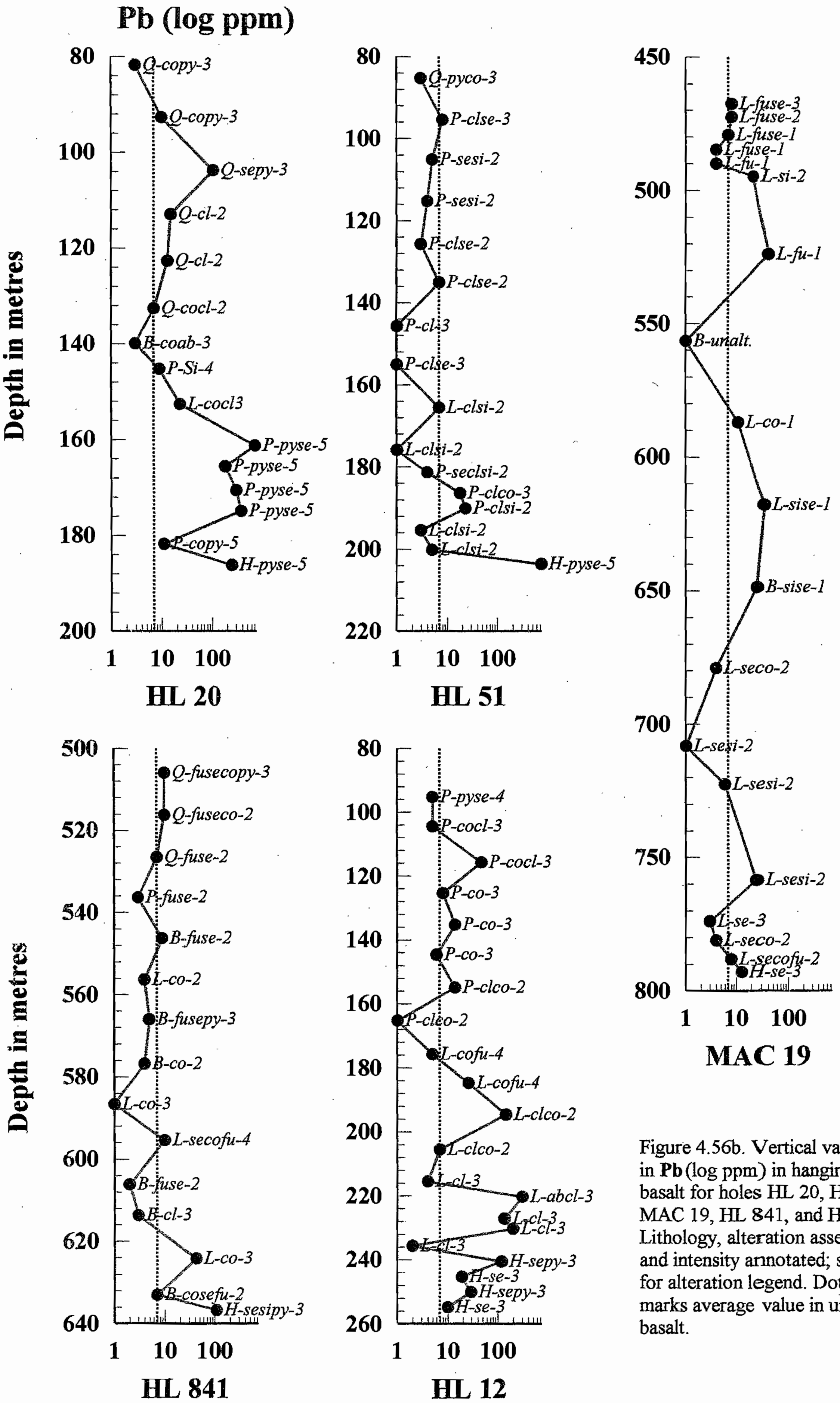


Figure 4.56b. Vertical variation in **Pb** (log ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

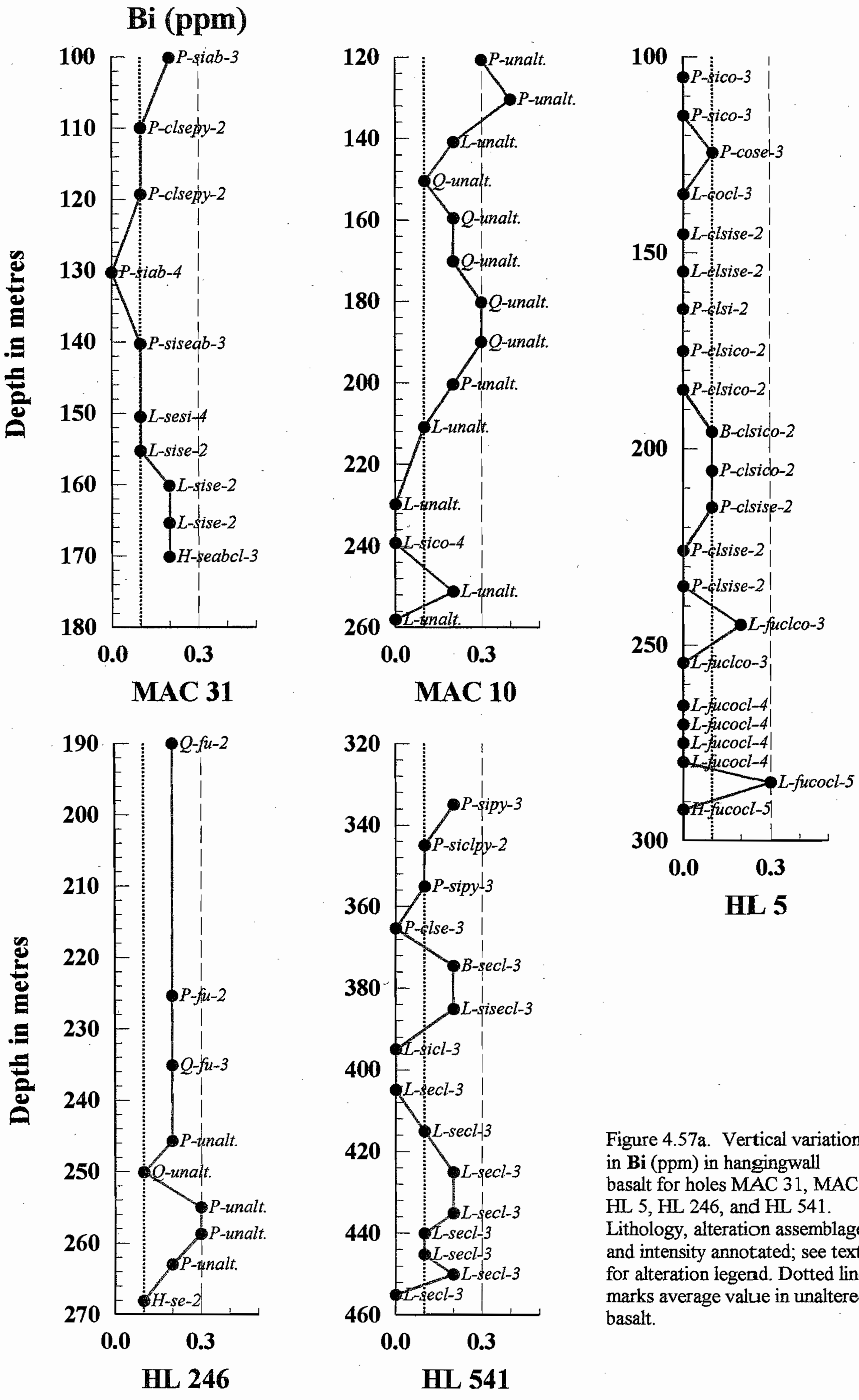


Figure 4.57a. Vertical variation in **Bi** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

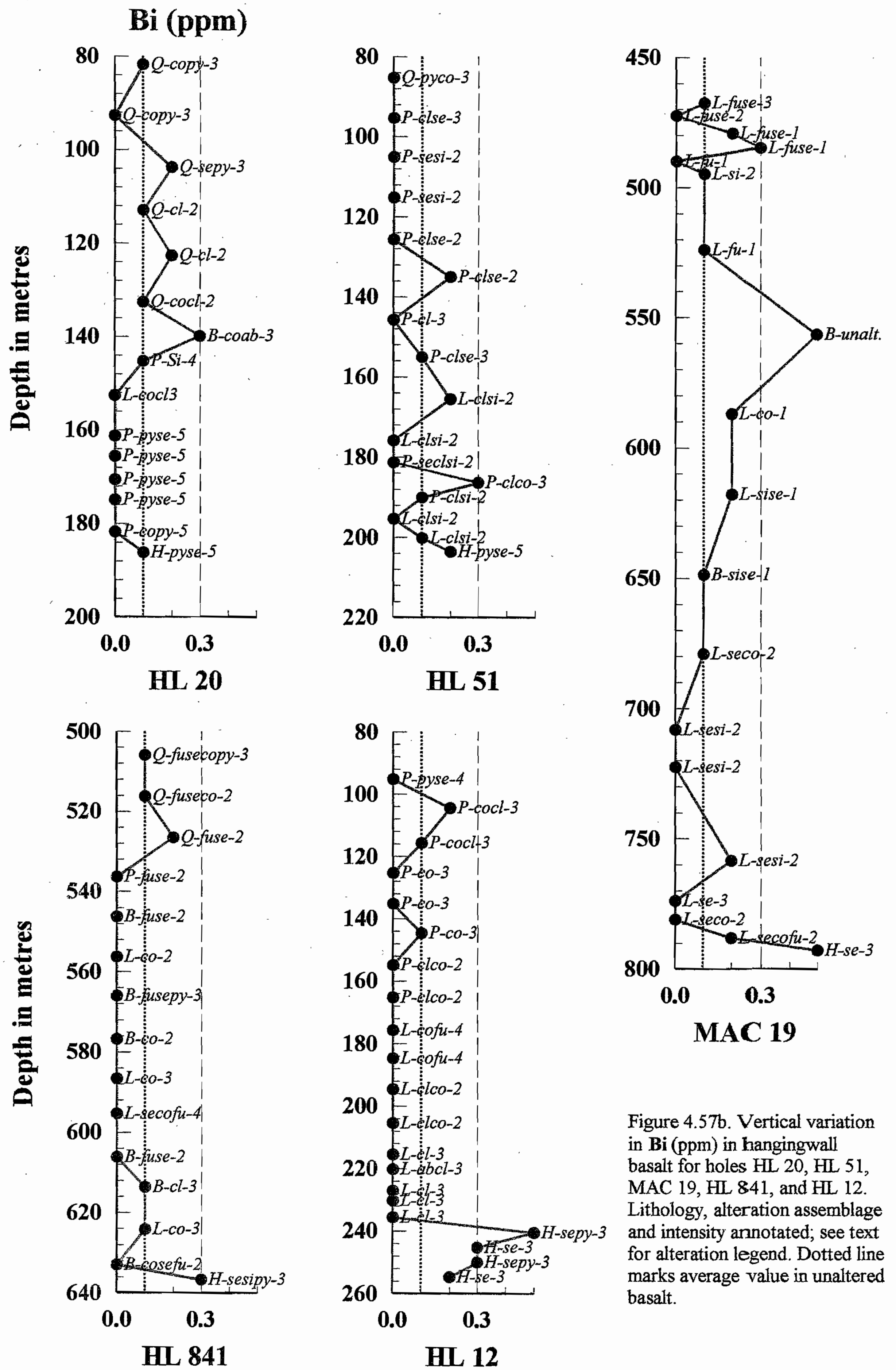


Figure 4.57b. Vertical variation in **Bi** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

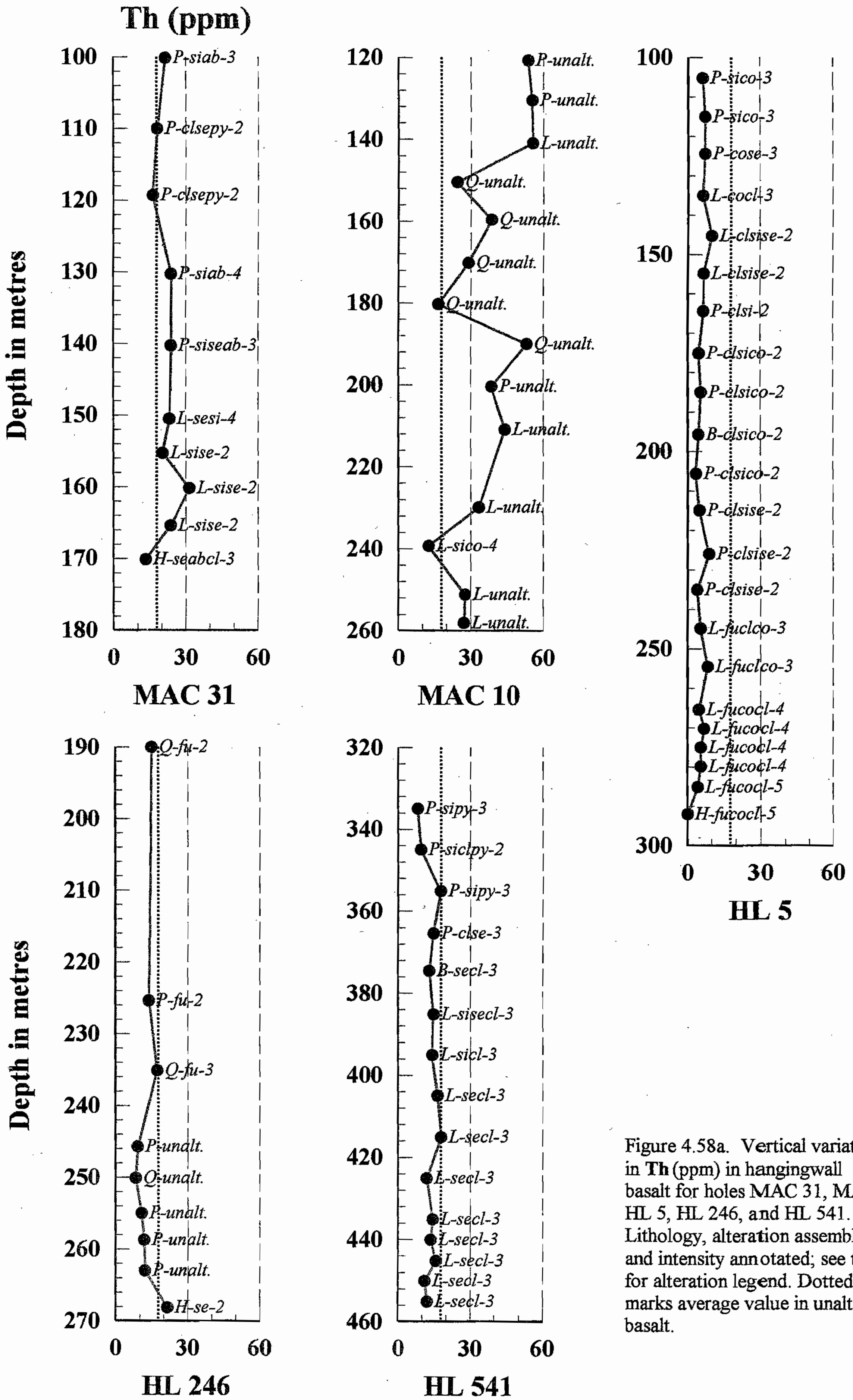


Figure 4.58a. Vertical variation in **Th** (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

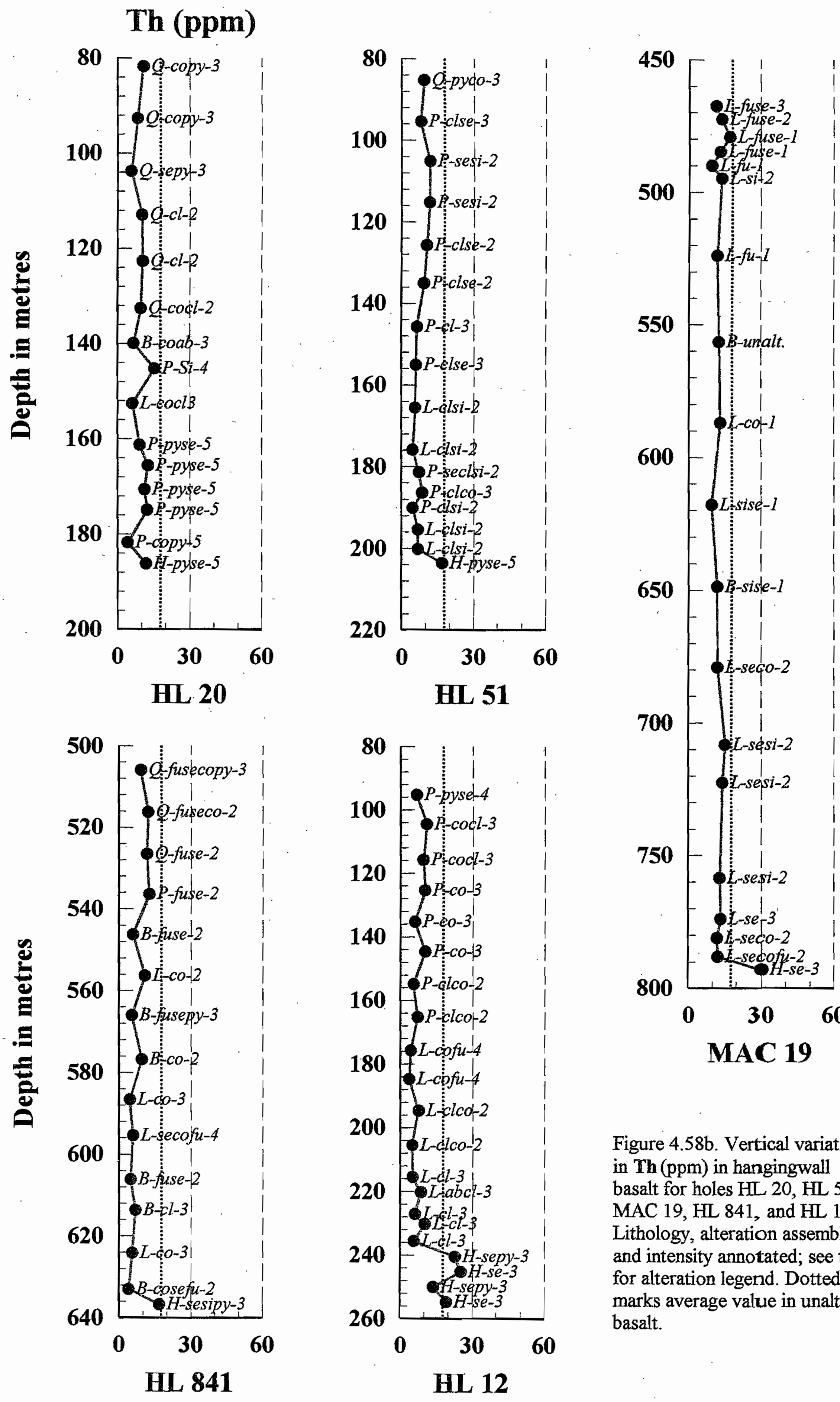


Figure 4.58b. Vertical variation in **Th** (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

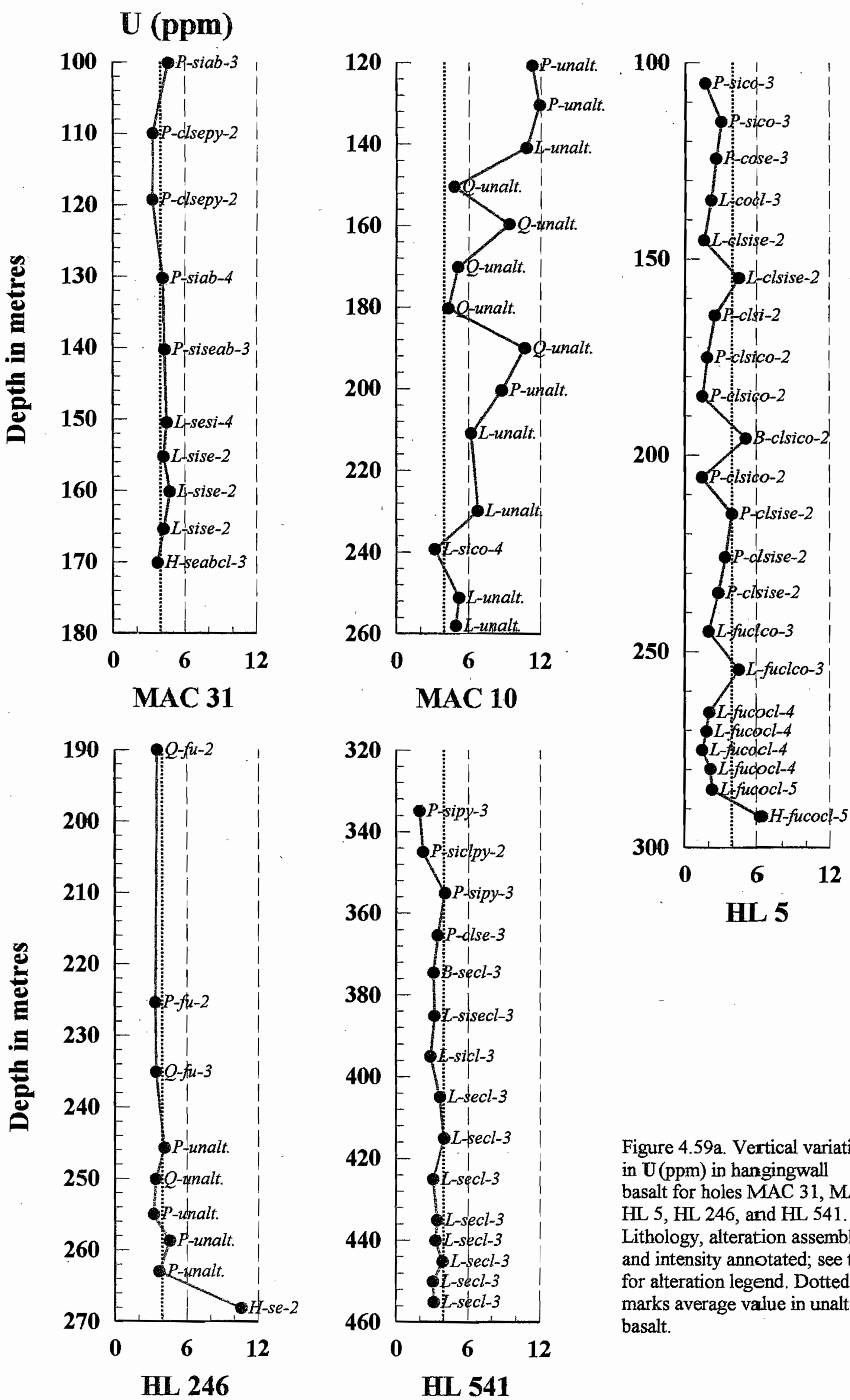


Figure 4.59a. Vertical variation in U (ppm) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

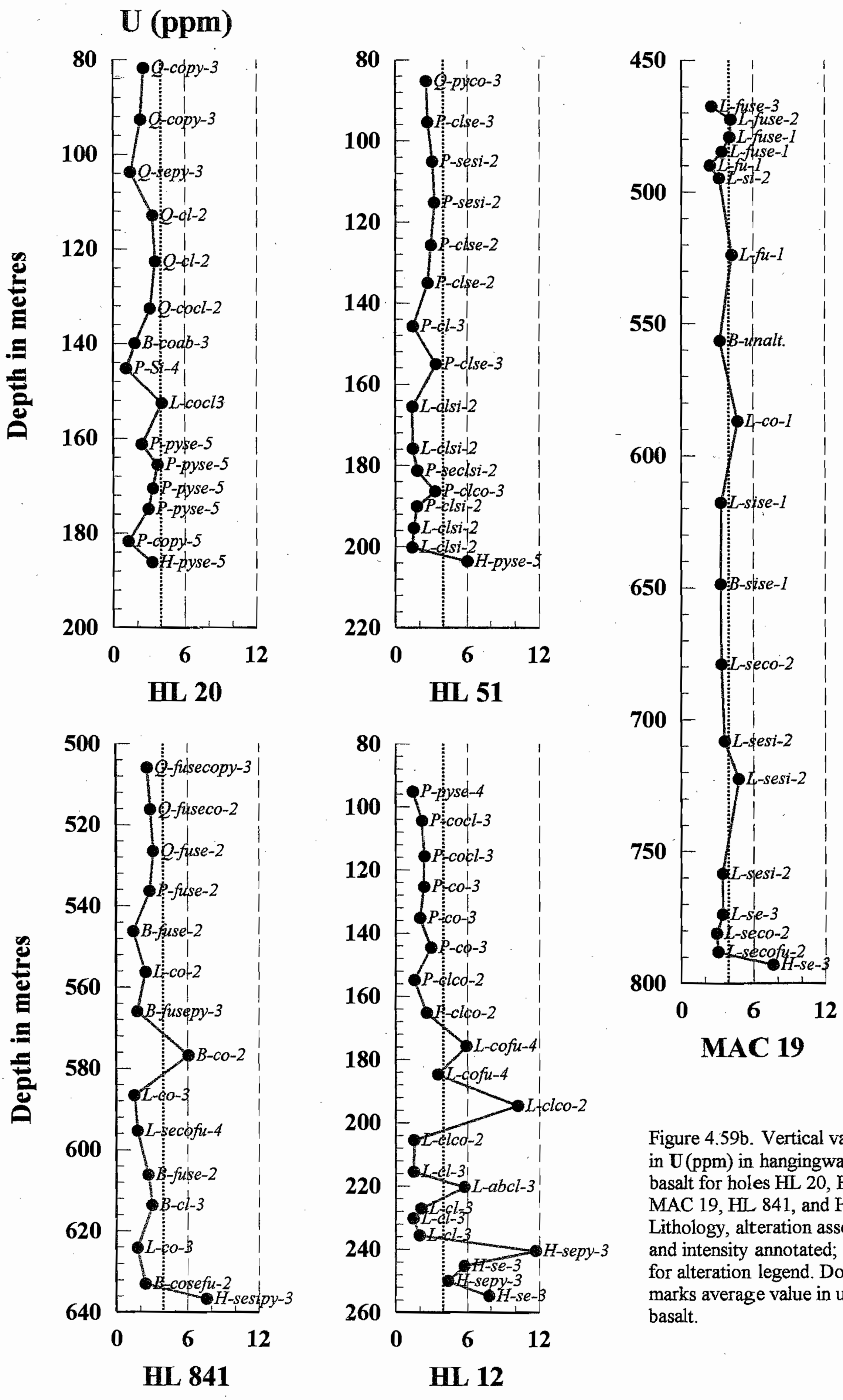


Figure 4.59b. Vertical variation in U (ppm) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

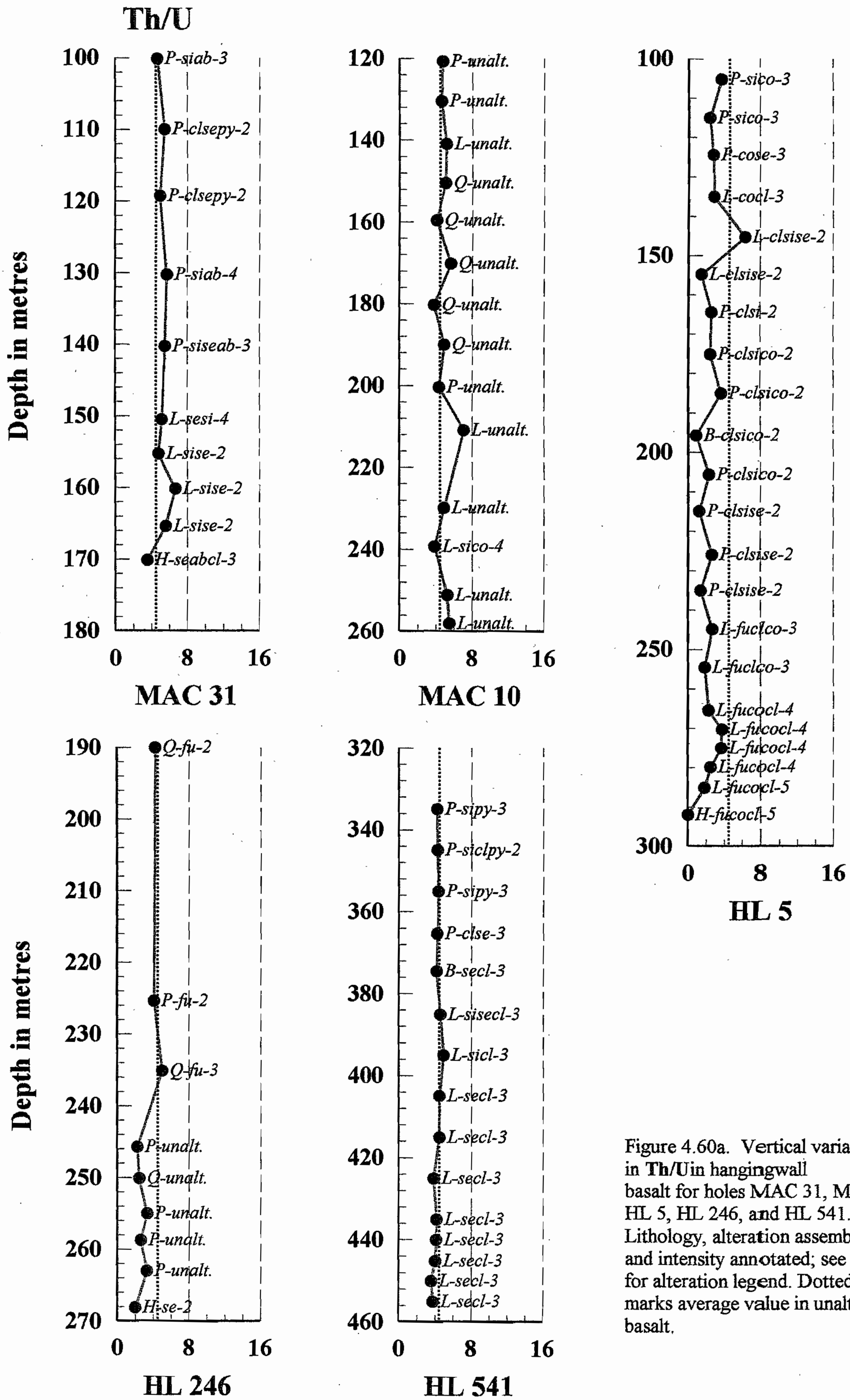


Figure 4.60a. Vertical variation in **Th/U** in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

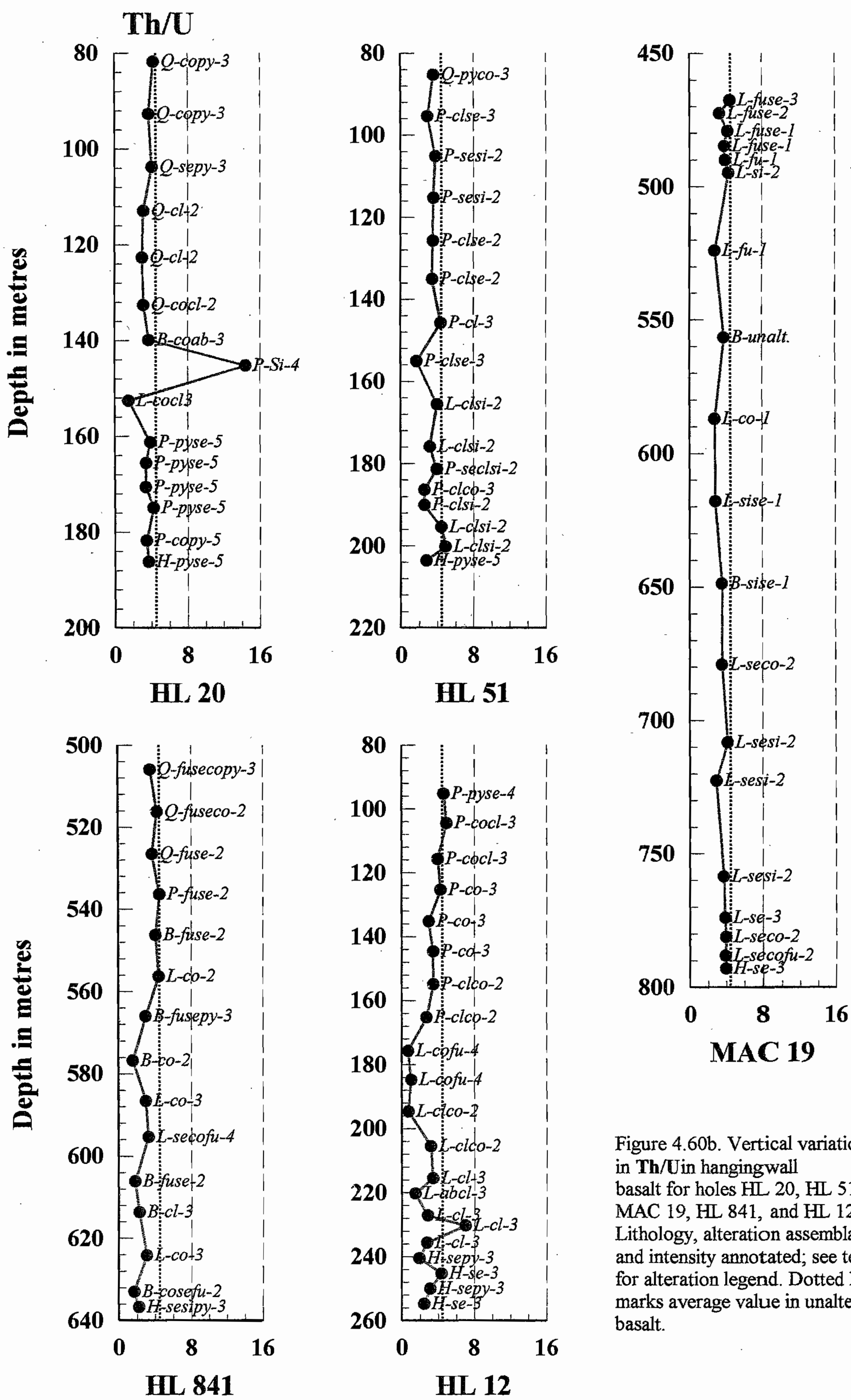


Figure 4.60b. Vertical variation in **Th/U**in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

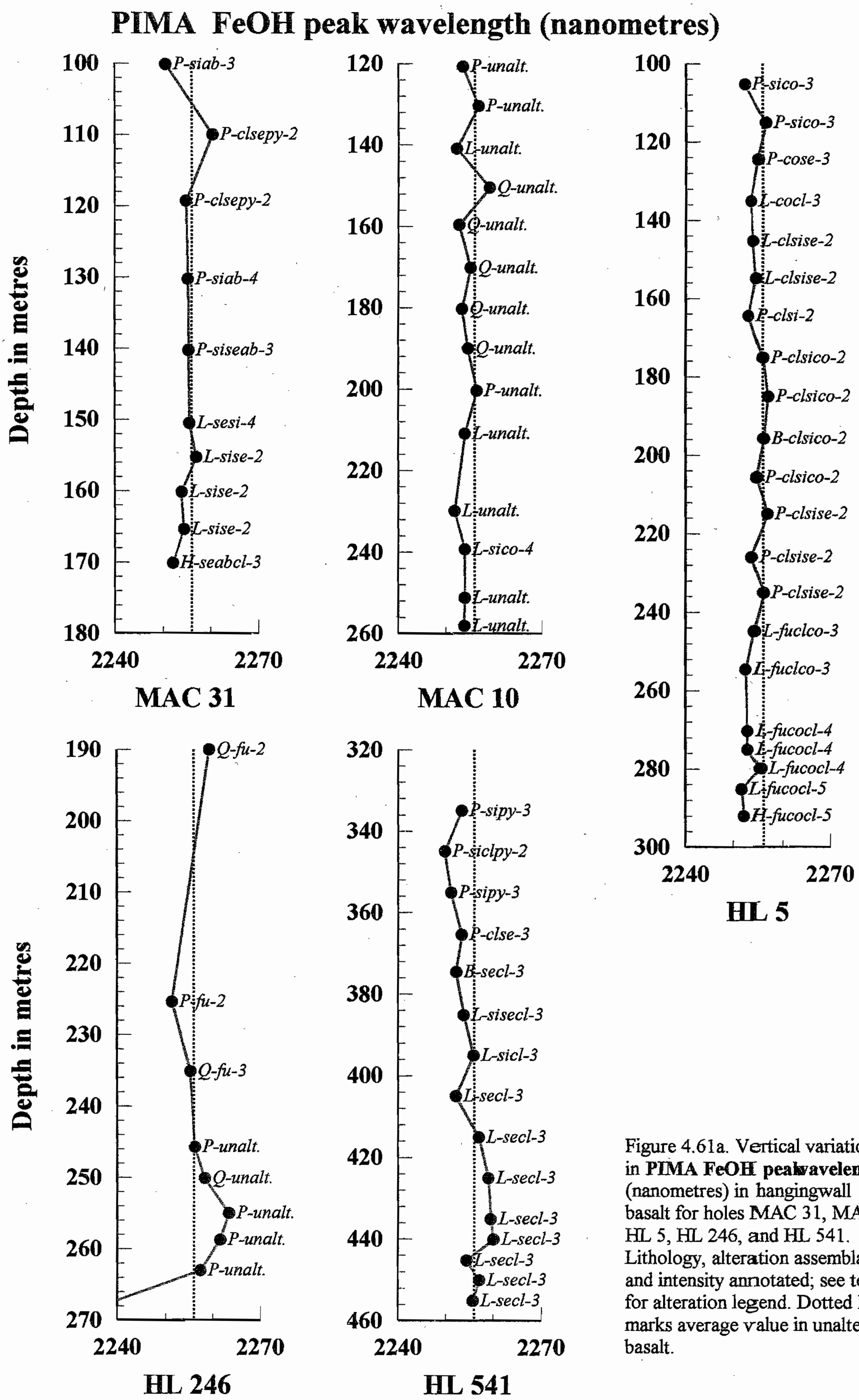


Figure 4.61a. Vertical variation in **PIMA FeOH peakwavelength** (nanometres) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

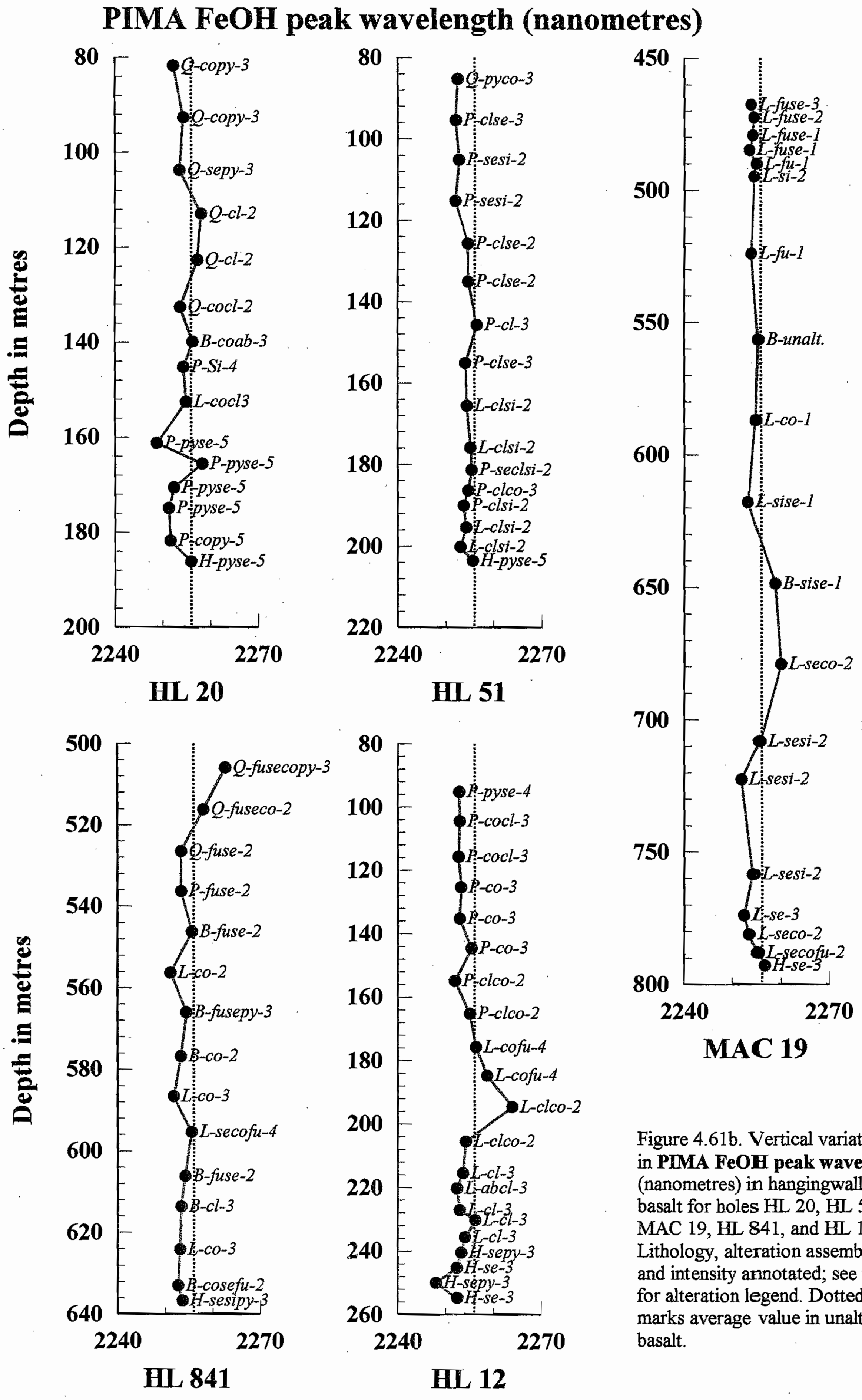


Figure 4.61b. Vertical variation in **PIMA FeOH peak wavelength** (nanometres) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

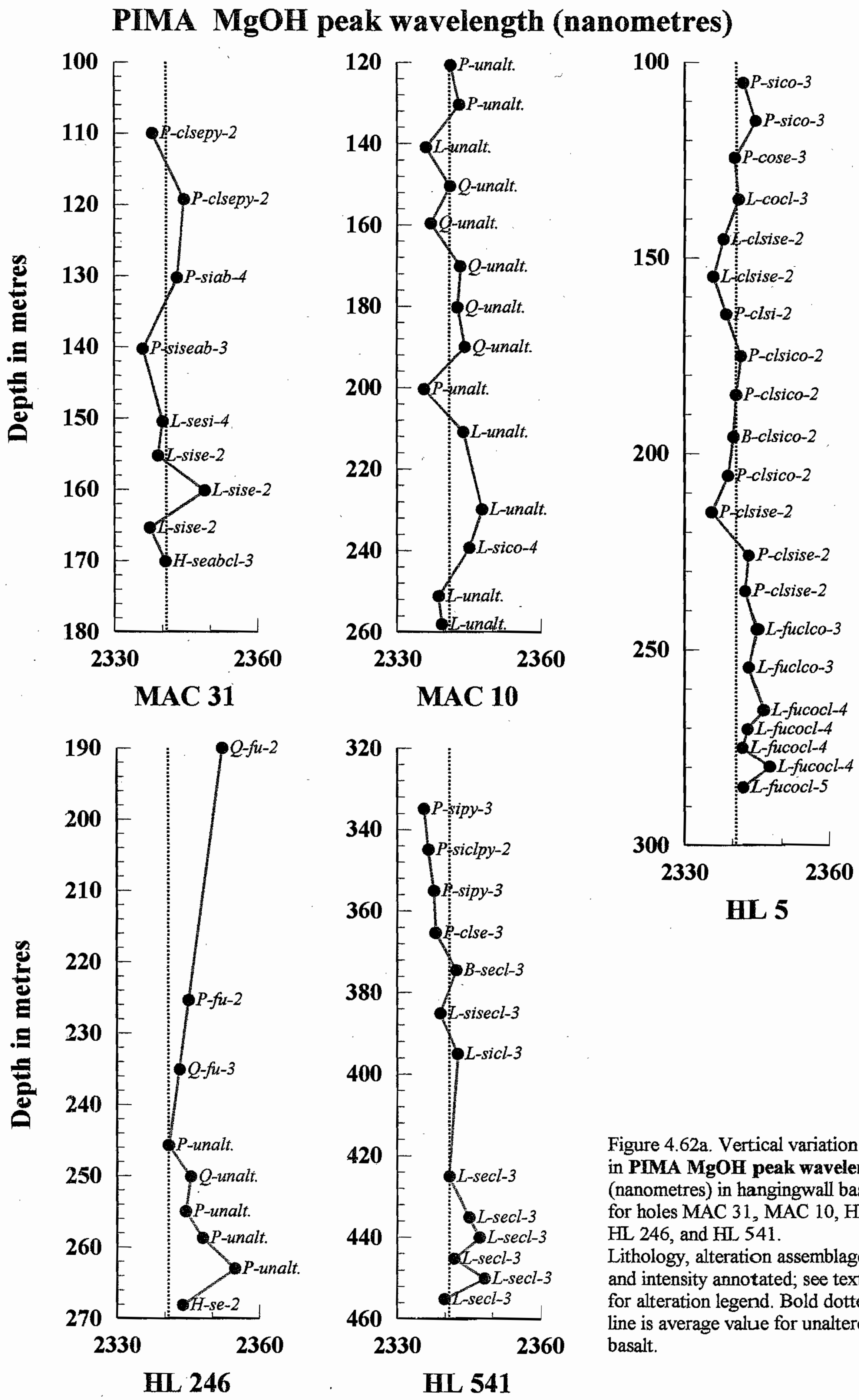


Figure 4.62a. Vertical variation in **PIMA MgOH peak wavelength** (nanometres) in hangingwall basalt for holes MAC 31, MAC 10, HL 5, HL 246, and HL 541. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Bold dotted line is average value for unaltered basalt.

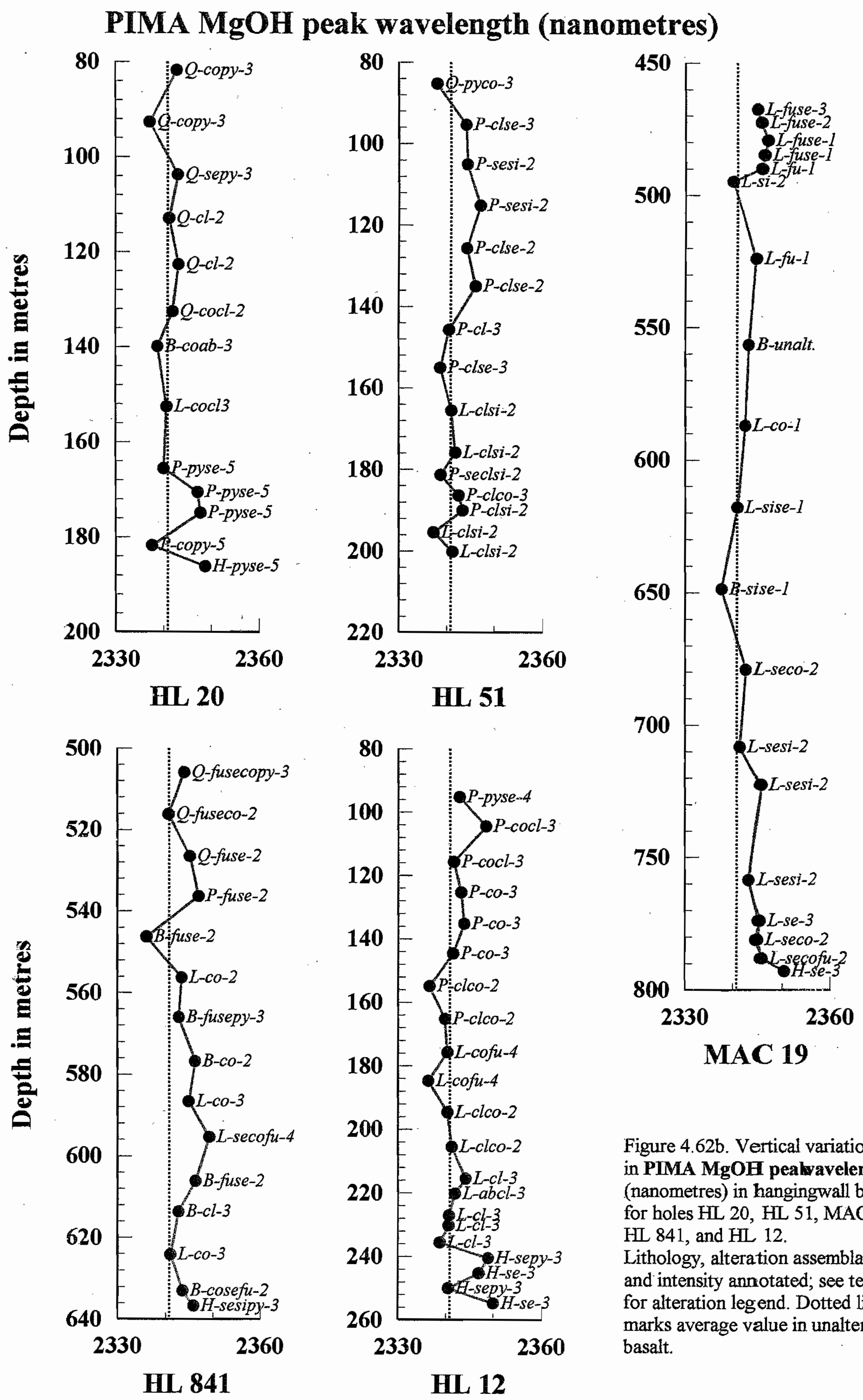


Figure 4.62b. Vertical variation in **PIMA MgOH peakwavelength** (nanometres) in hangingwall basalt for holes HL 20, HL 51, MAC 19, HL 841, and HL 12. Lithology, alteration assemblage and intensity annotated; see text for alteration legend. Dotted line marks average value in unaltered basalt.

Lateral variations

Data was plotted to see if there is any lateral geochemical zonation around the ore deposit. Major, trace element and other geochemical parameters have been plotted against distance from the ore deposit at three horizons. In Figure 4.63, the average of the two samples immediately above the HVS or lateral equivalent have been plotted for all holes. In Figure 4.64, the average of the two samples immedieately below the contact with the overlying Que River Shale have been plotted, and in Figure 4.65, a sample of the HVS or lateral equivalent has been used.

Within the basalt immediately above the HVS horizon, as the ore deposit is approached there is a consistent increase in Sb. There are also increases in some proximal holes for Ca, K, Ba, S, C, Ba/Sr, Cu, Zn, As, Rb, Cs, Tl, Hellyer Alteration Index, Ti/Zr, Cr and Ni. The latter three elements may be higher because the samples are taken from the core lava. There are decreases in Si, Mg, Na, P, Nb, Zr, La, Ce, Nd, Th, and U, although all of these elements except Na may be lower because the samples are from the core lava.

Within the basalt immediately below the Que River Shale, as the deposit position is approached there is a significant increase in Sb. There are also increases in some of the proximal holes for Fe (significant pyrite in some samples), Mn, Ca, Ba, Ishikawa Alteration Index, Ba/Sr, Zn, and Tl. There are decreases in Ca, and Na.

Within the HVS, as the deposit is approached, there are significant increases in Sb again. There are also increase in Si, Ba, Ba/Sr, Ishikawa Alteration Index, Zn, Cu, Pb, As, Cd, and Tl. There are decreases in Ti, Ca, Ti/Zr, Ishikawa Alteration Index, Sc, V, Cr, Ni, and Sr.

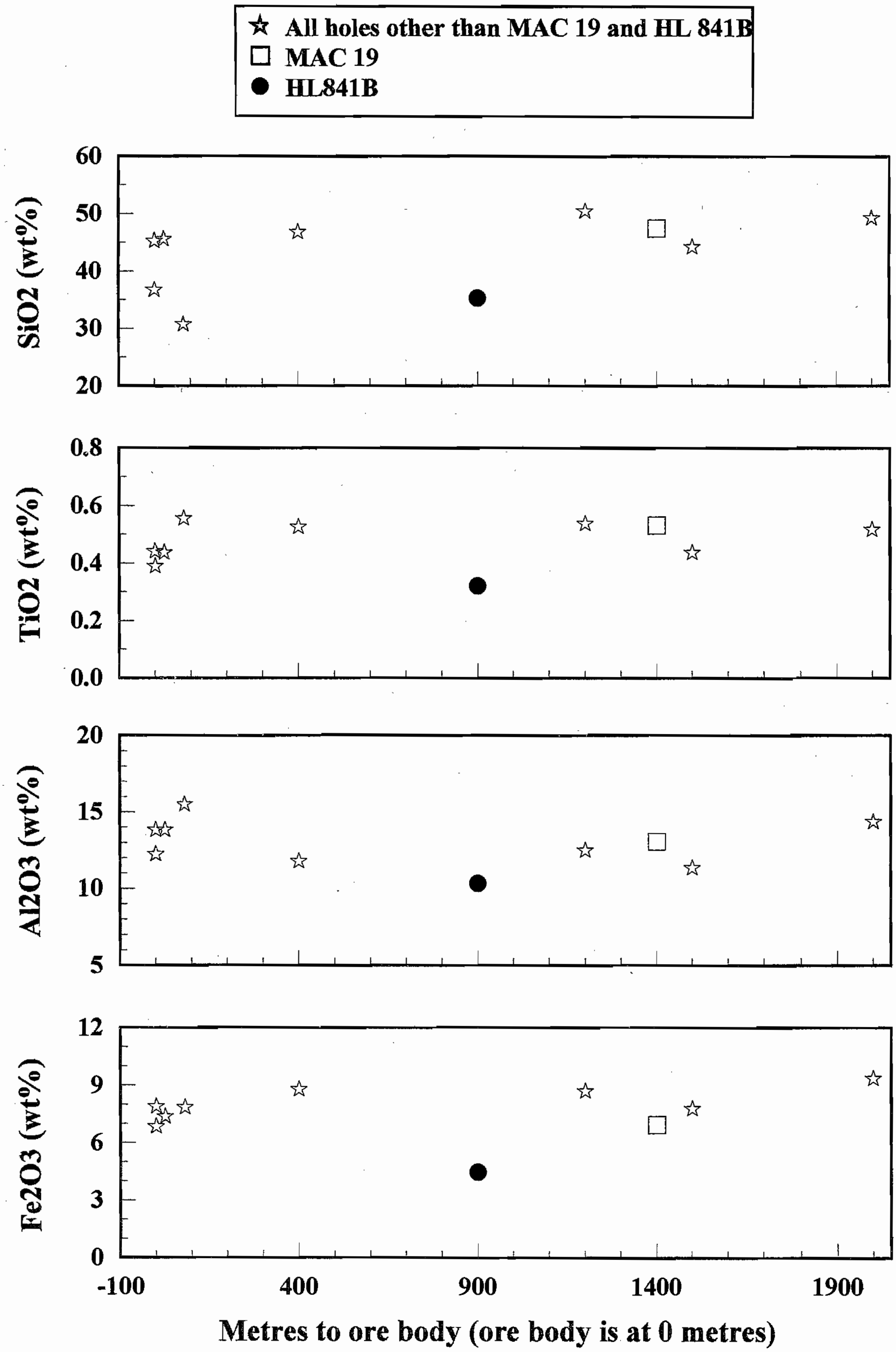


Figure 4.63a Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

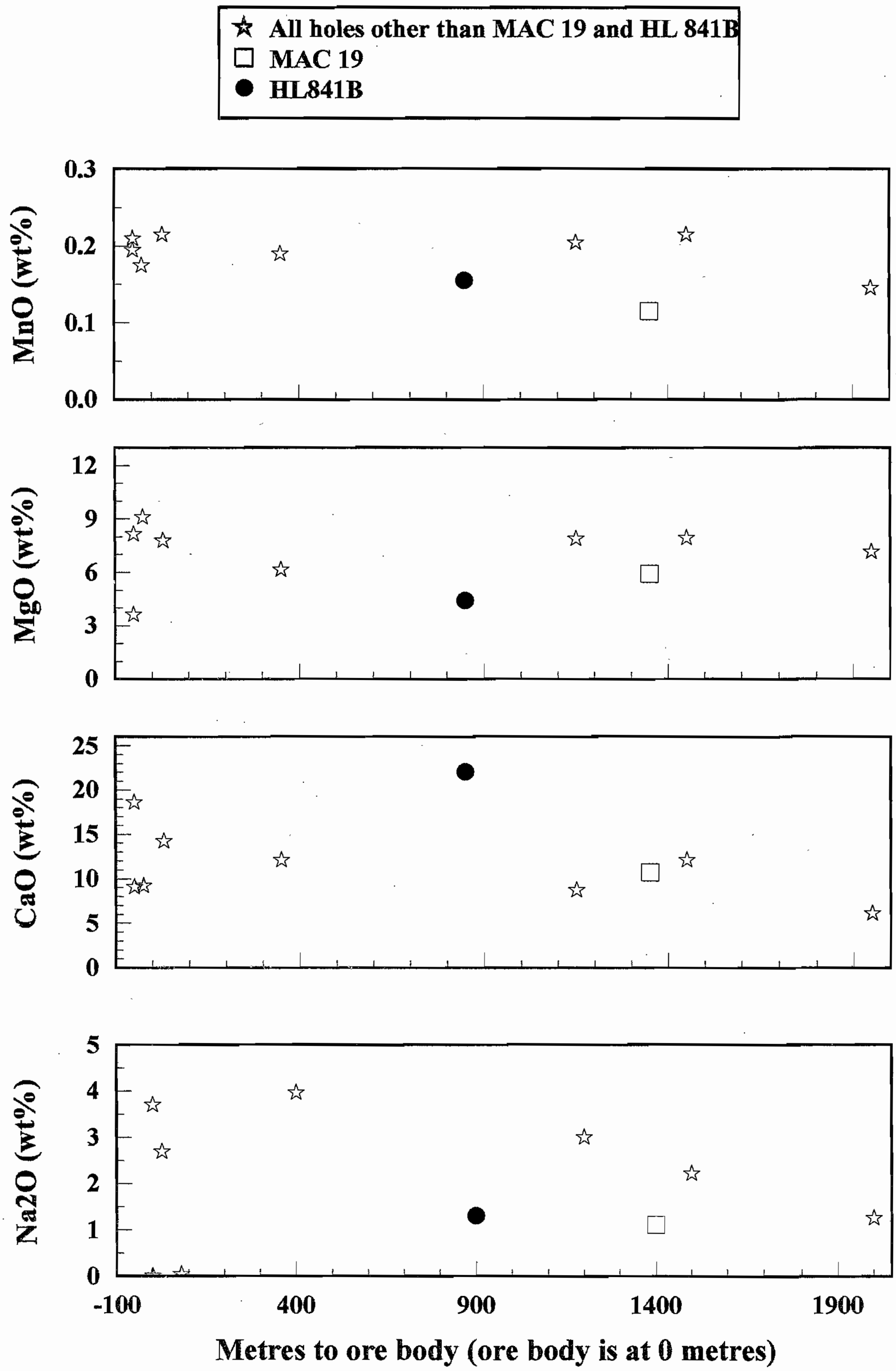


Figure 4.63b Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

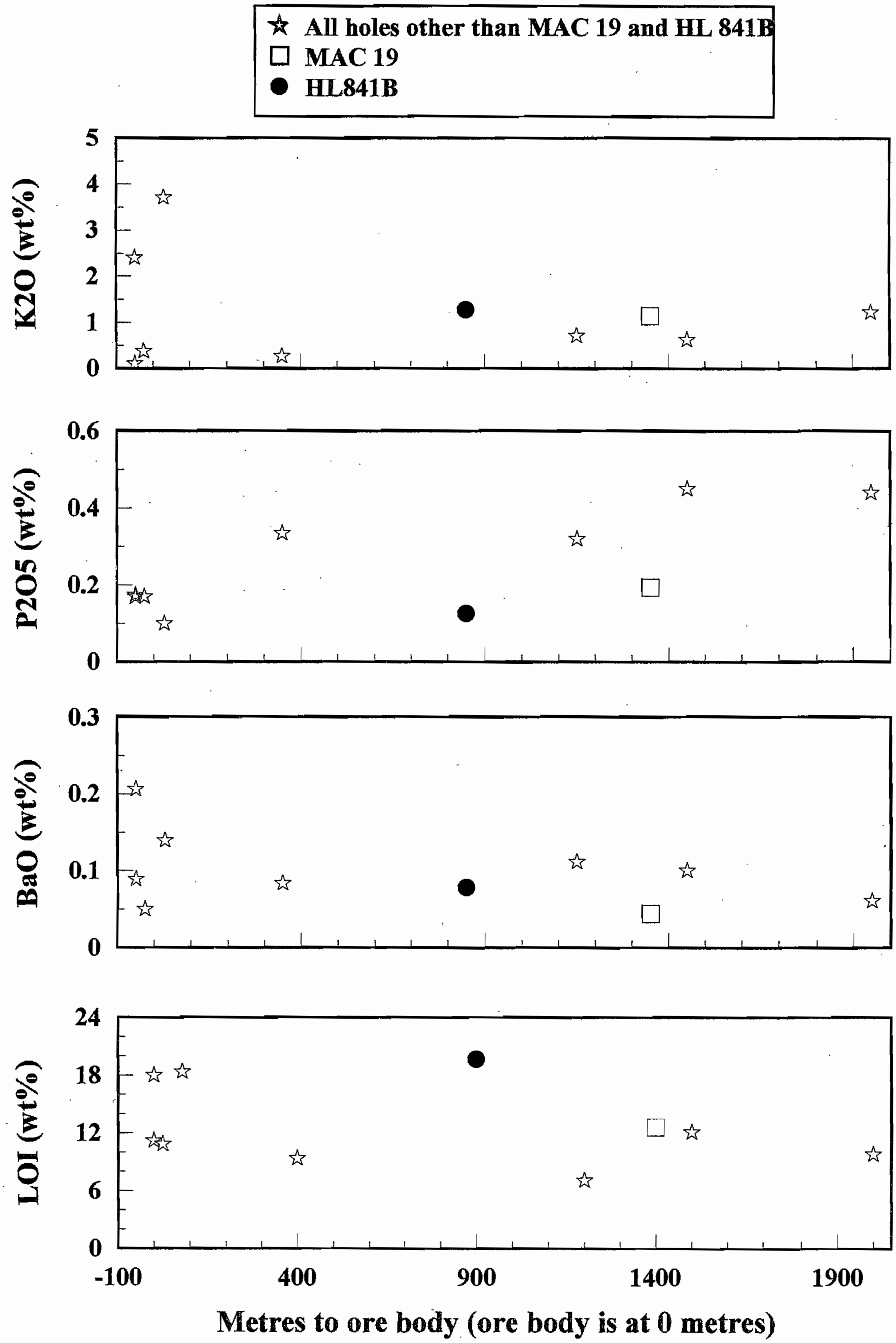


Figure 4.63c Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

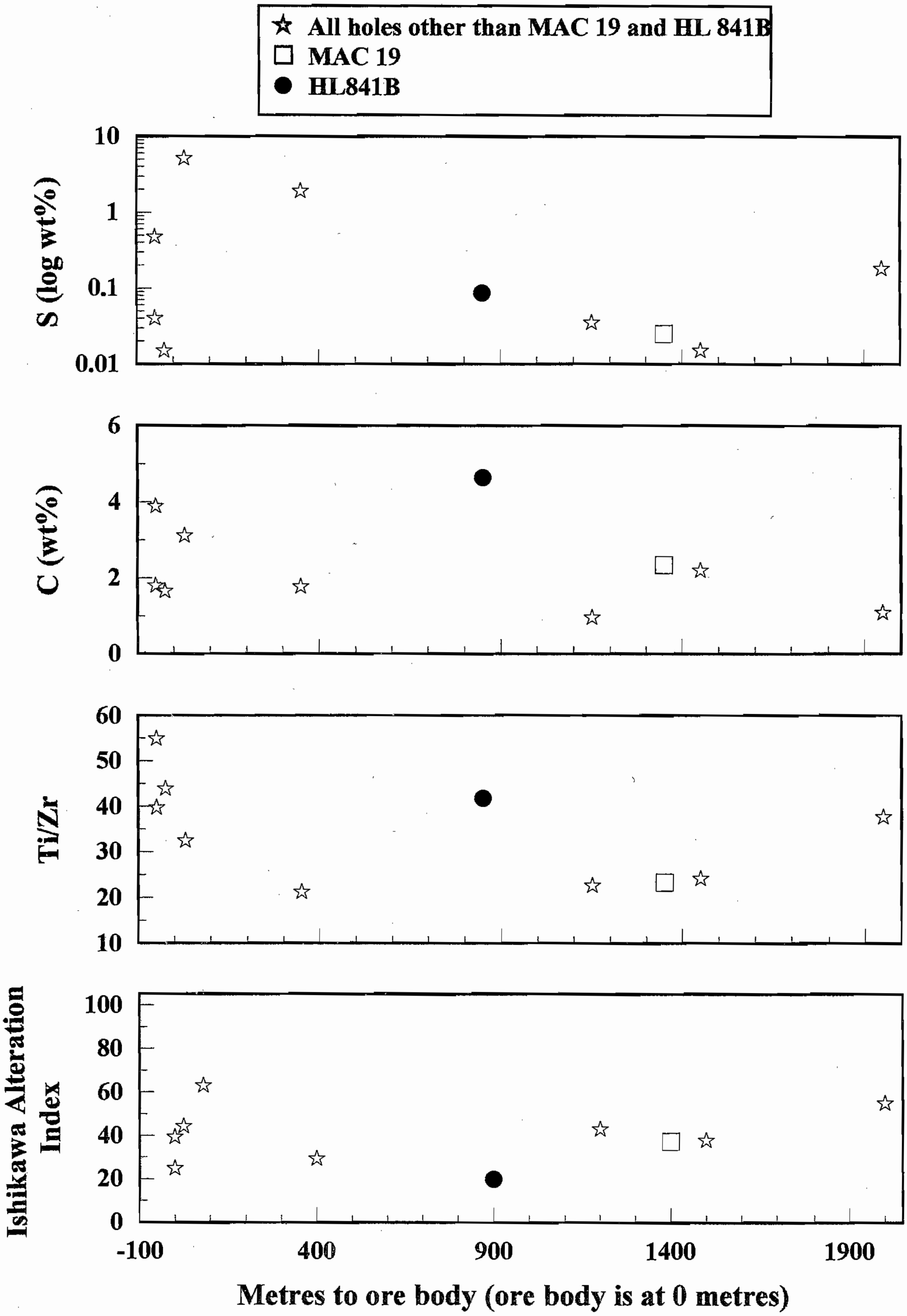


Figure 4.63d Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

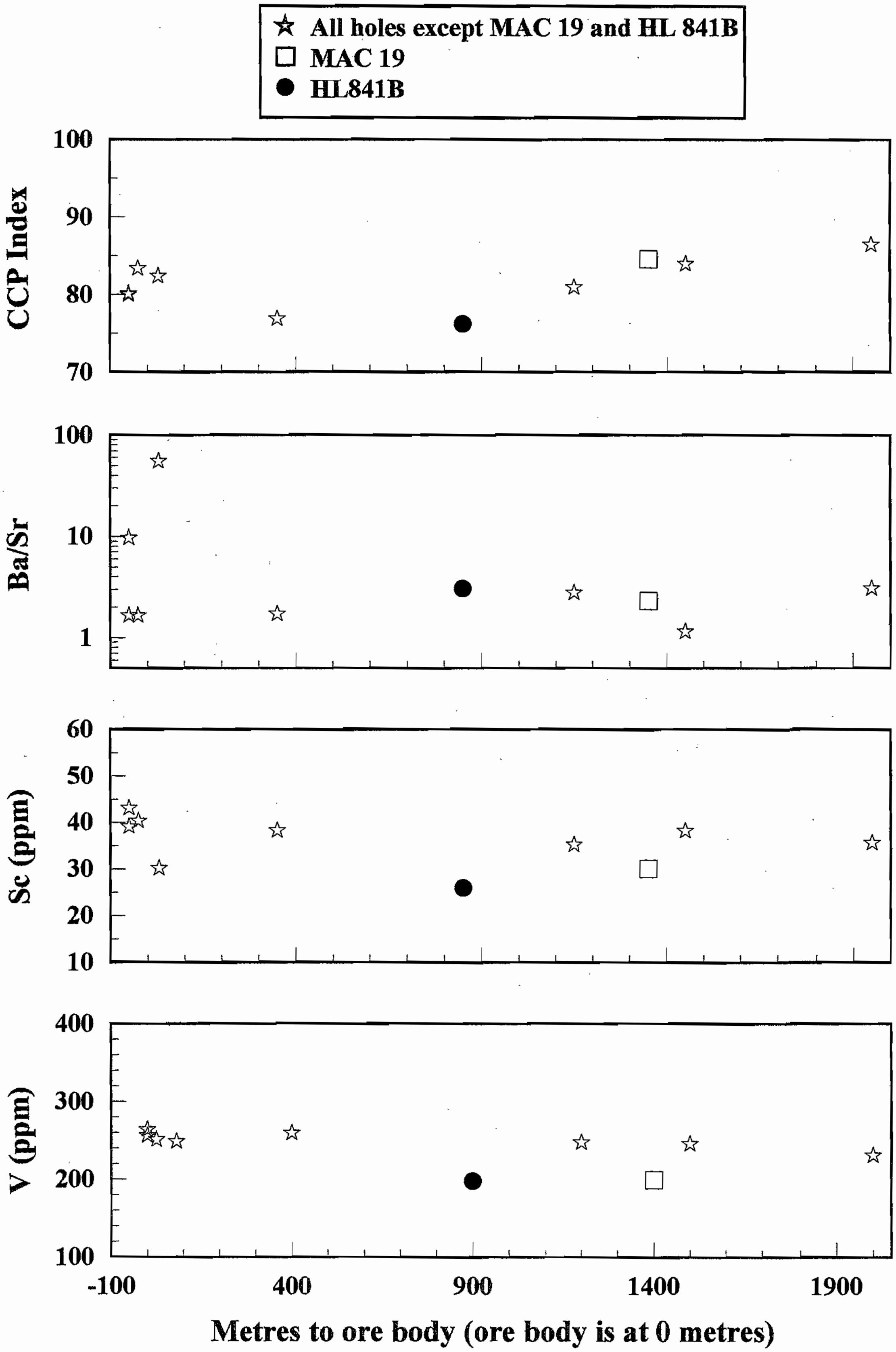


Figure 4.63e Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

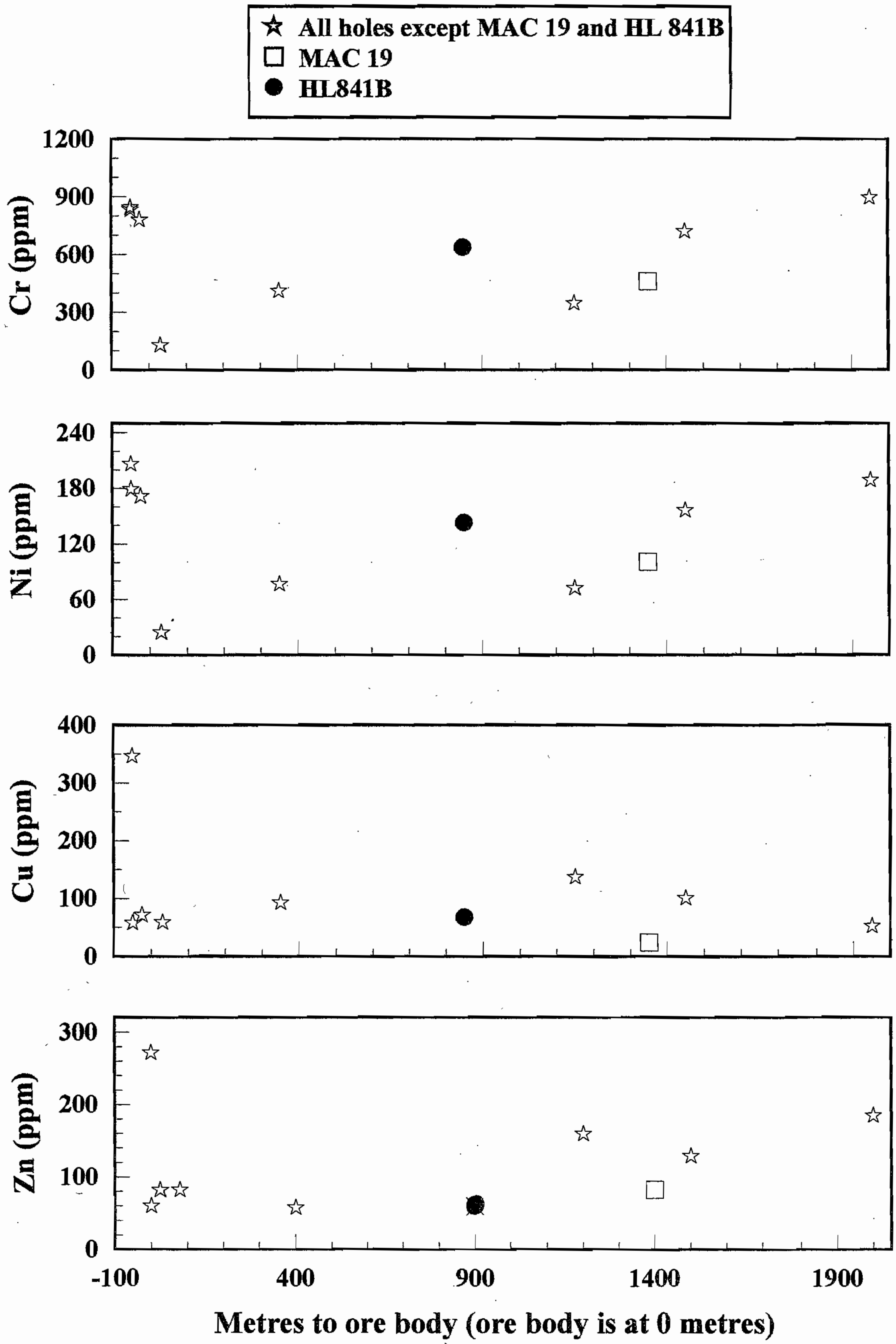


Figure 4.63f Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

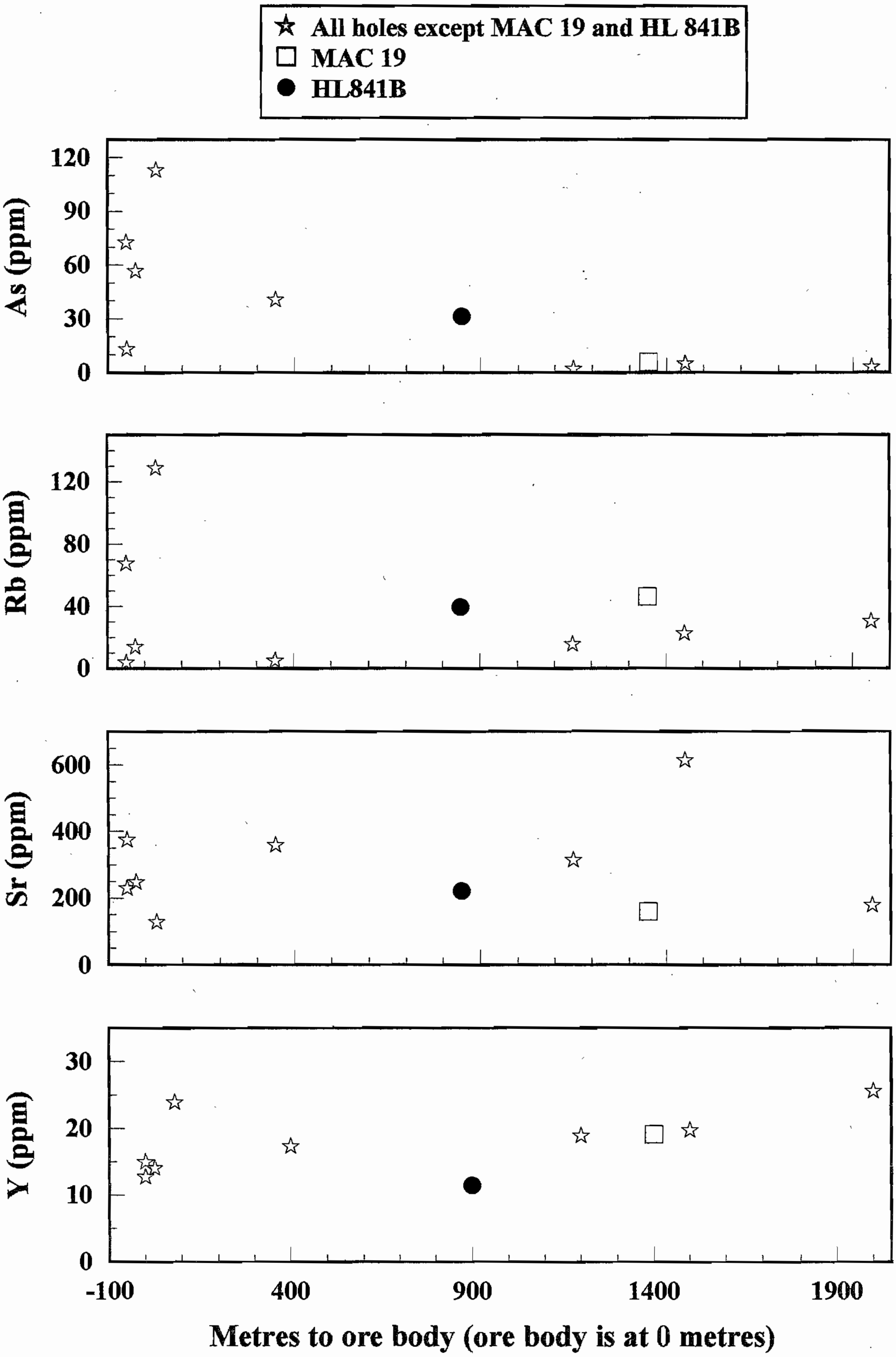


Figure 4.63g Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

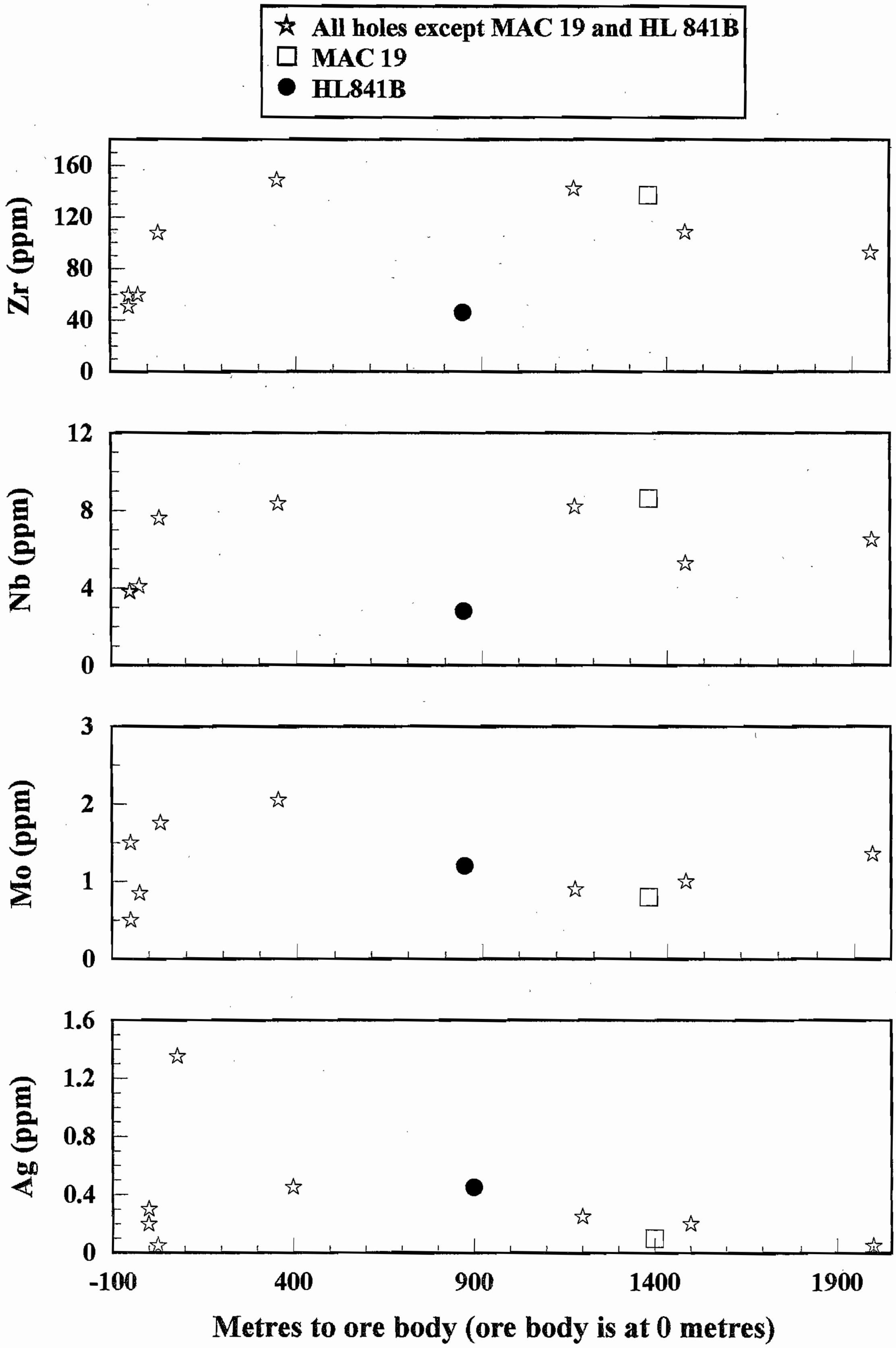


Figure 4.63h Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

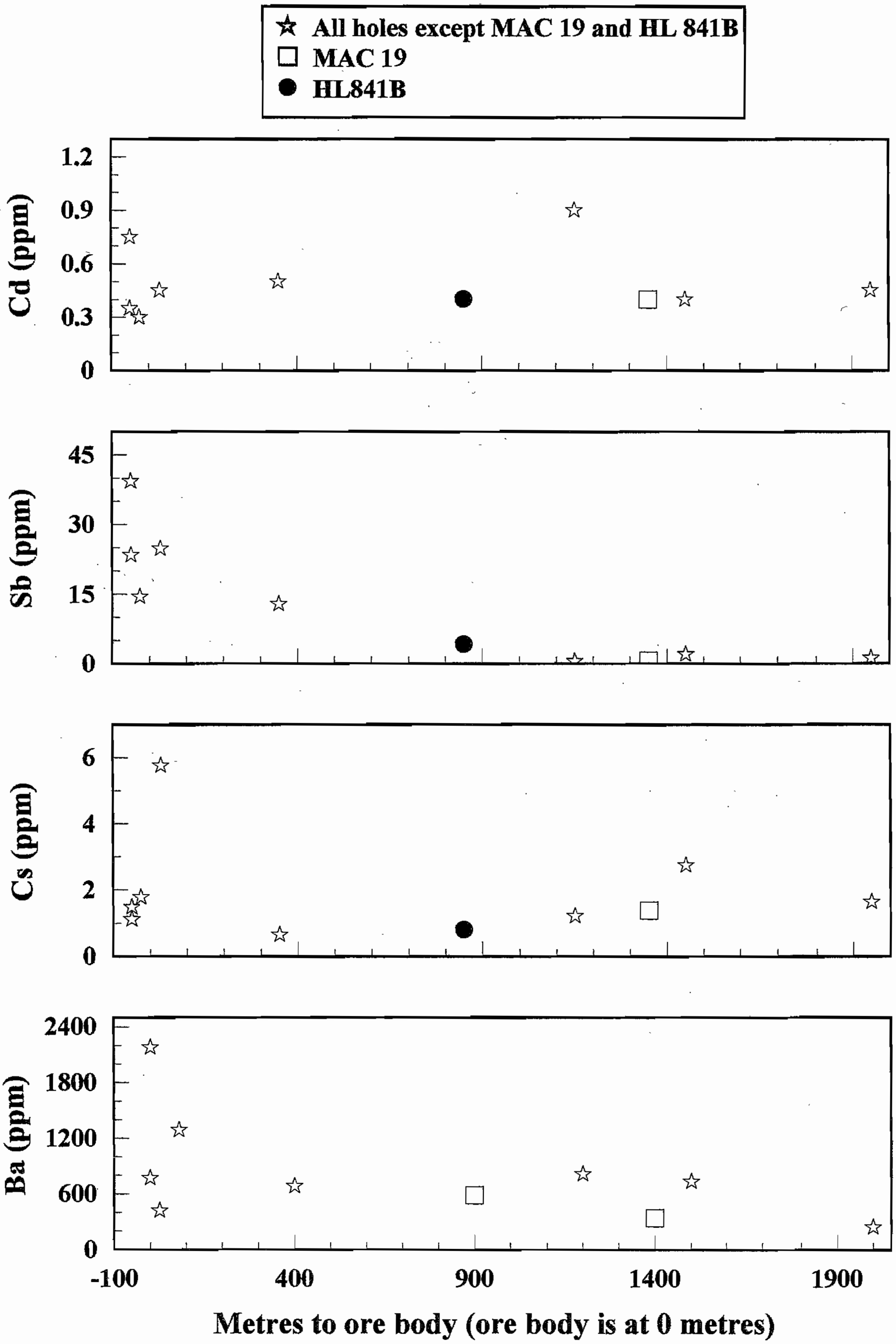


Figure 4.63i Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

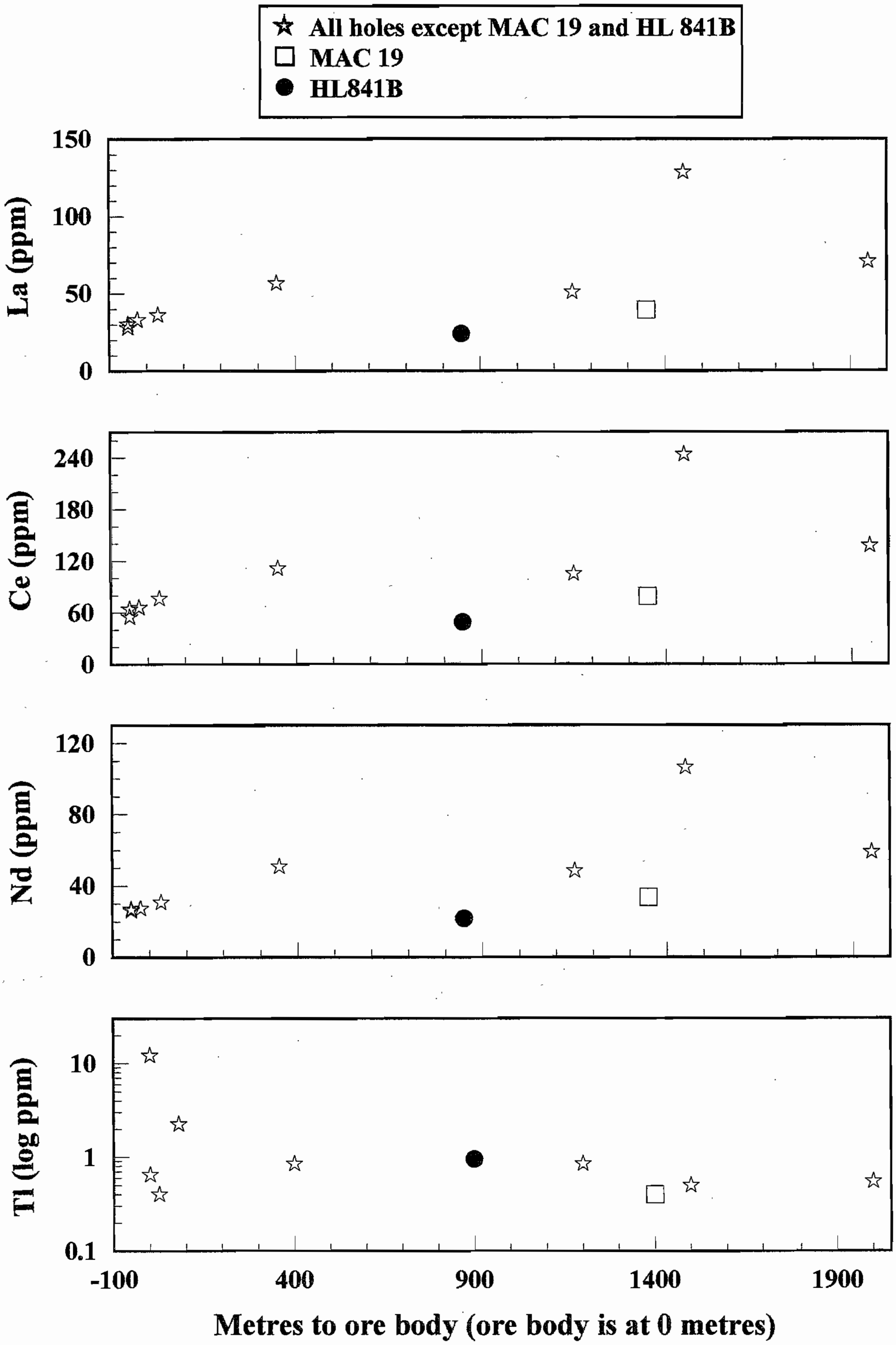


Figure 4.63j Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

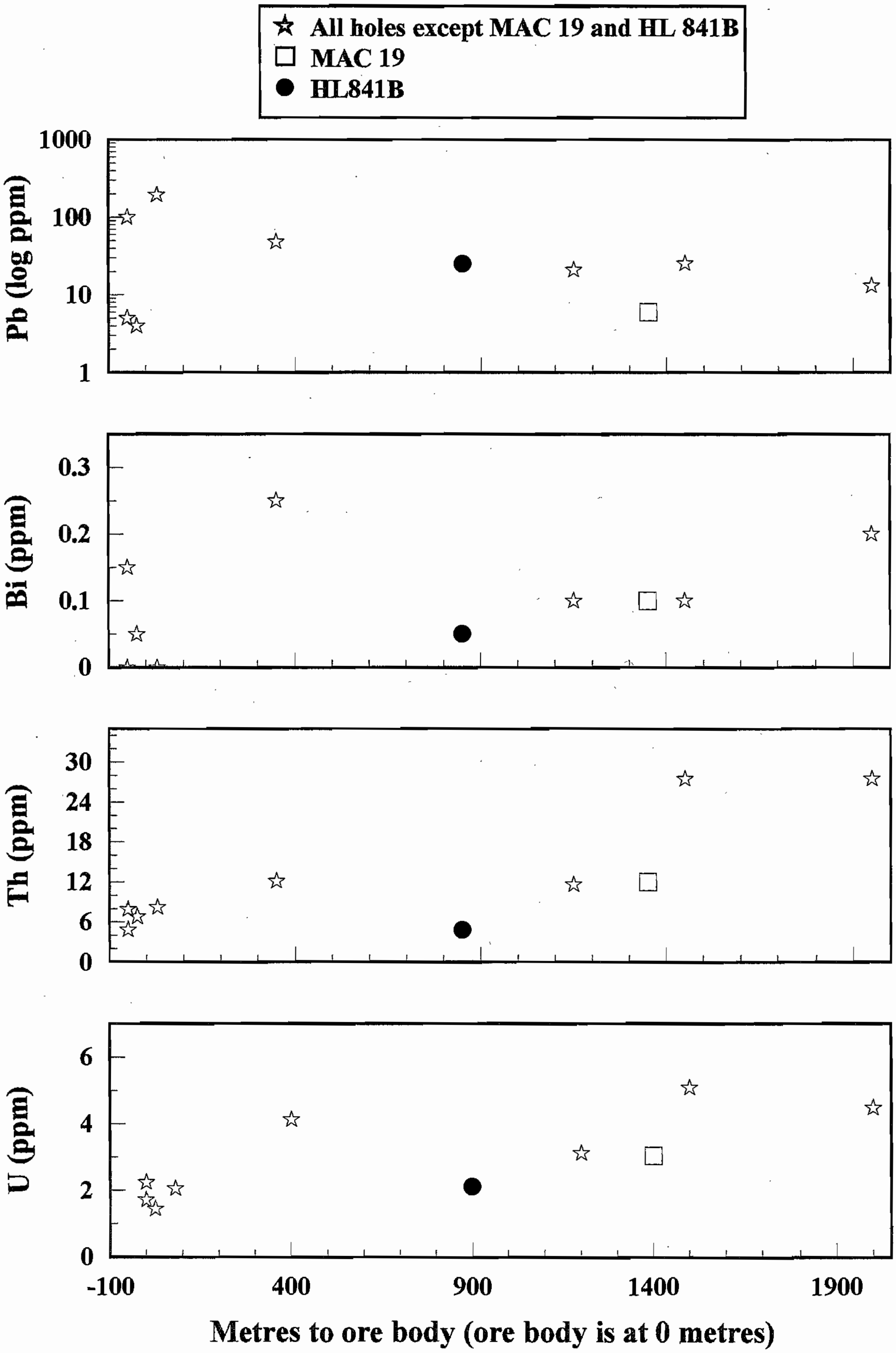


Figure 4.63k Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

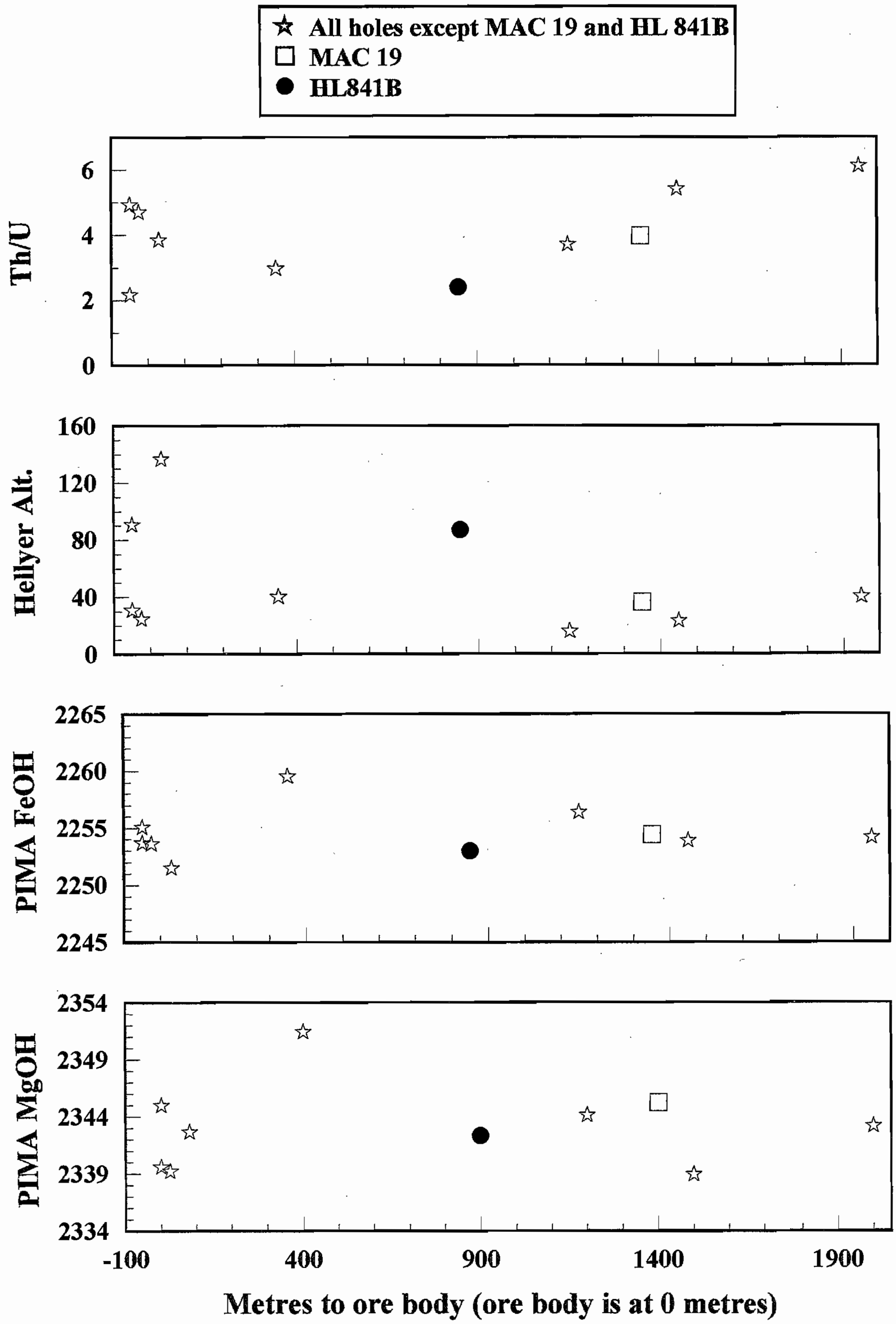


Figure 4.631 Hellyer basalt chemistry versus horizontal distance from ore body. Average of two samples taken from immediately above the HVS or lateral equivalent. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

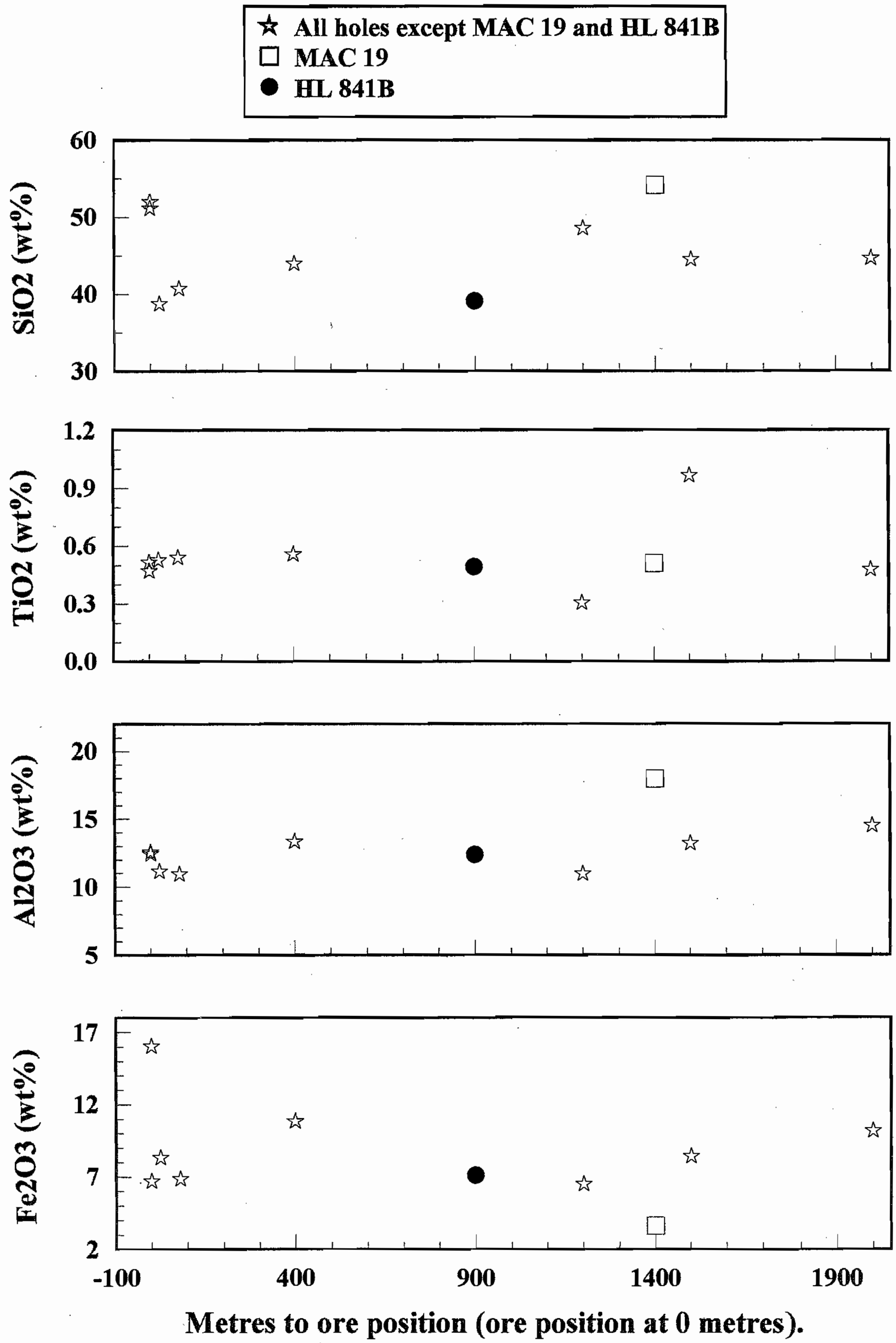


Figure 4.64a Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

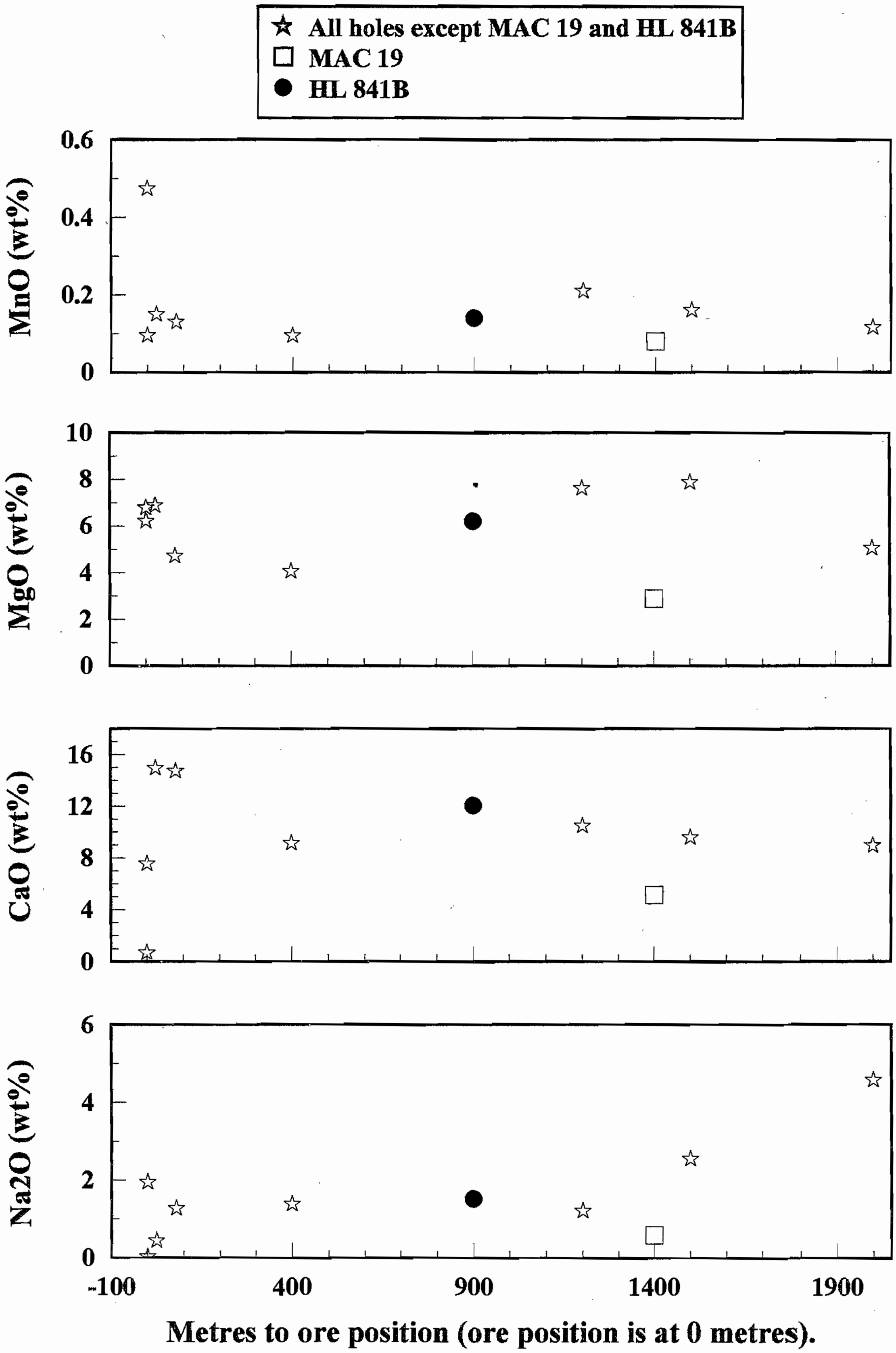


Figure 4.64b Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

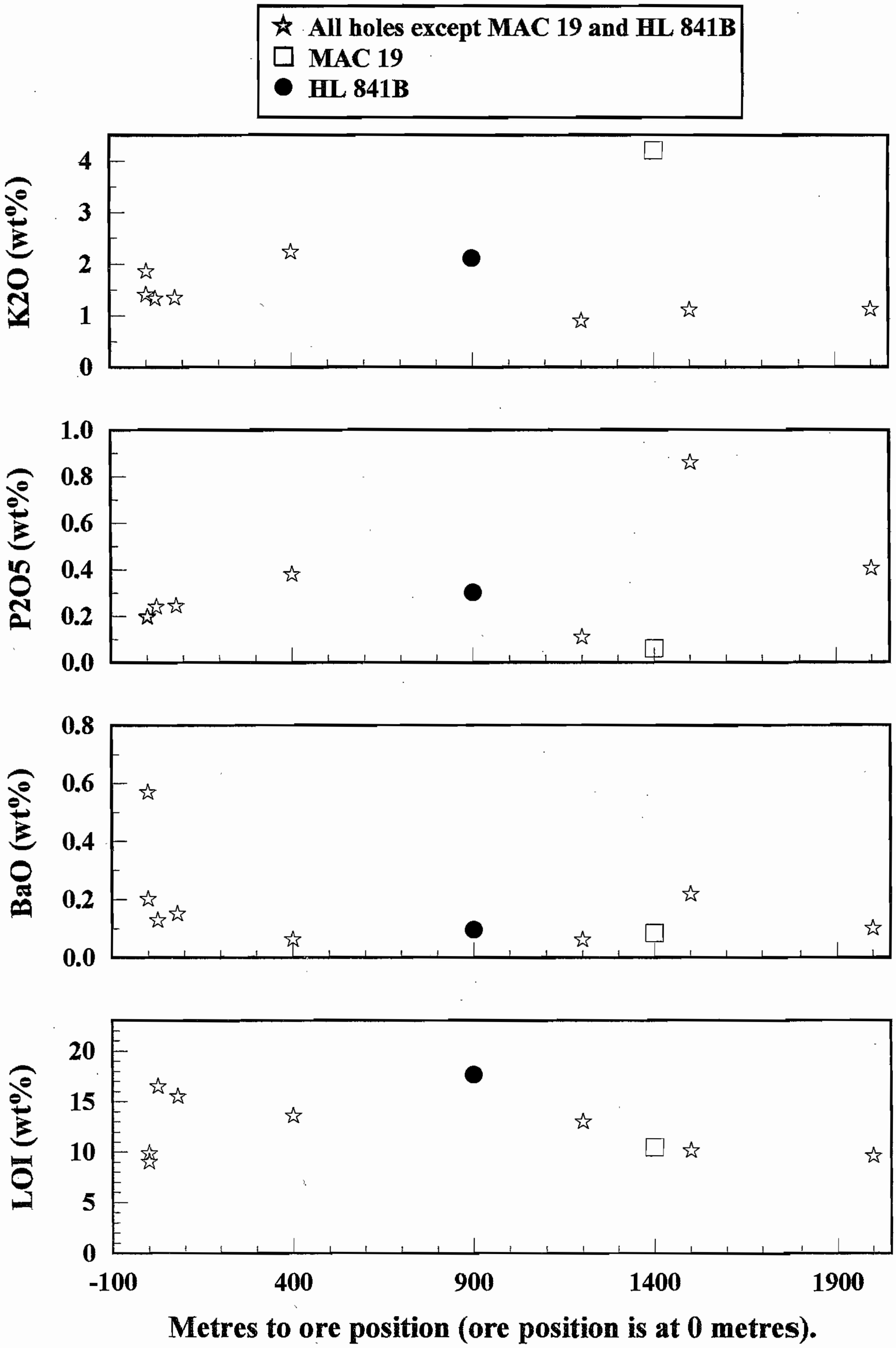


Figure 4.64c Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

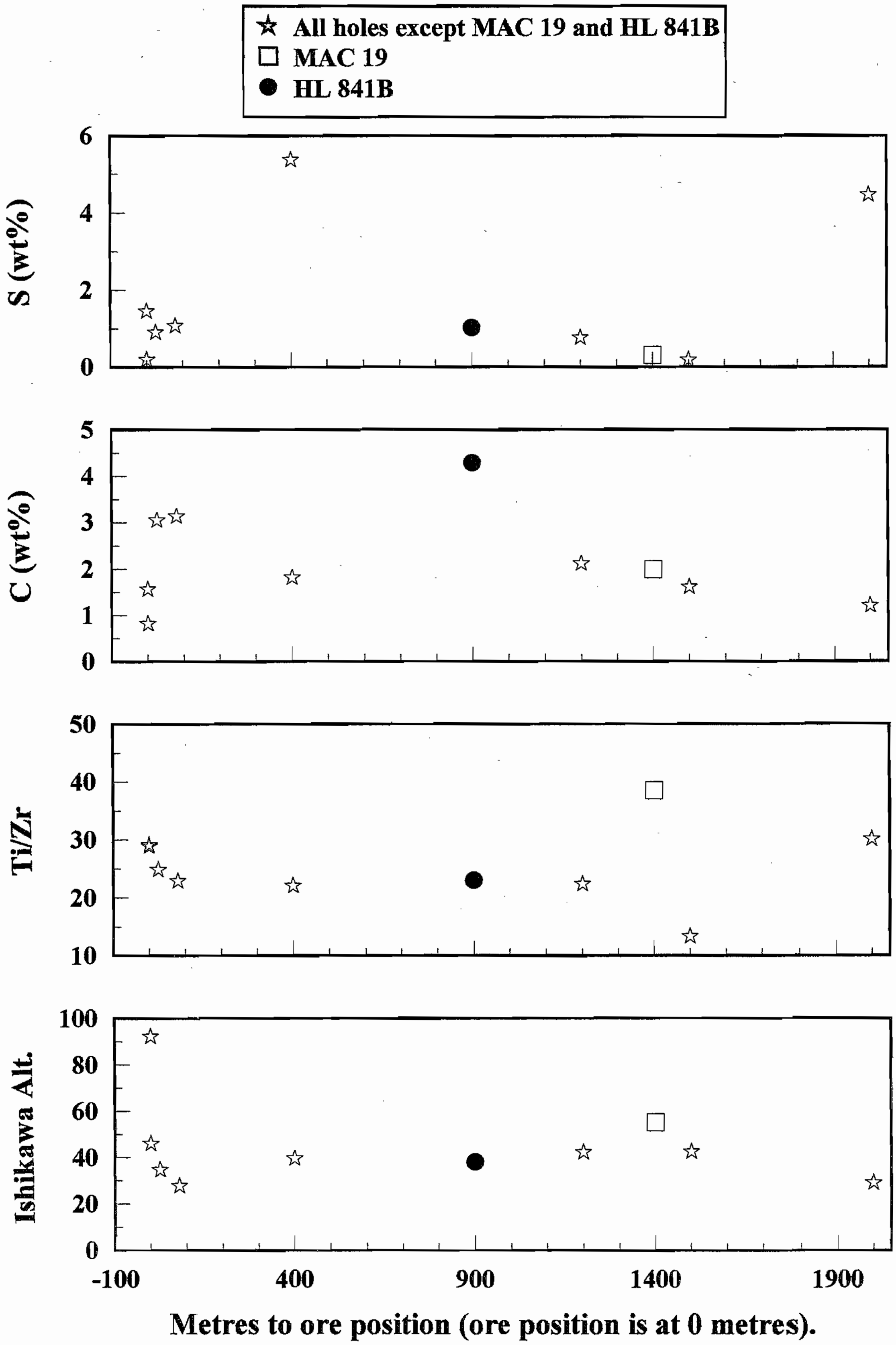


Figure 4.64d Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

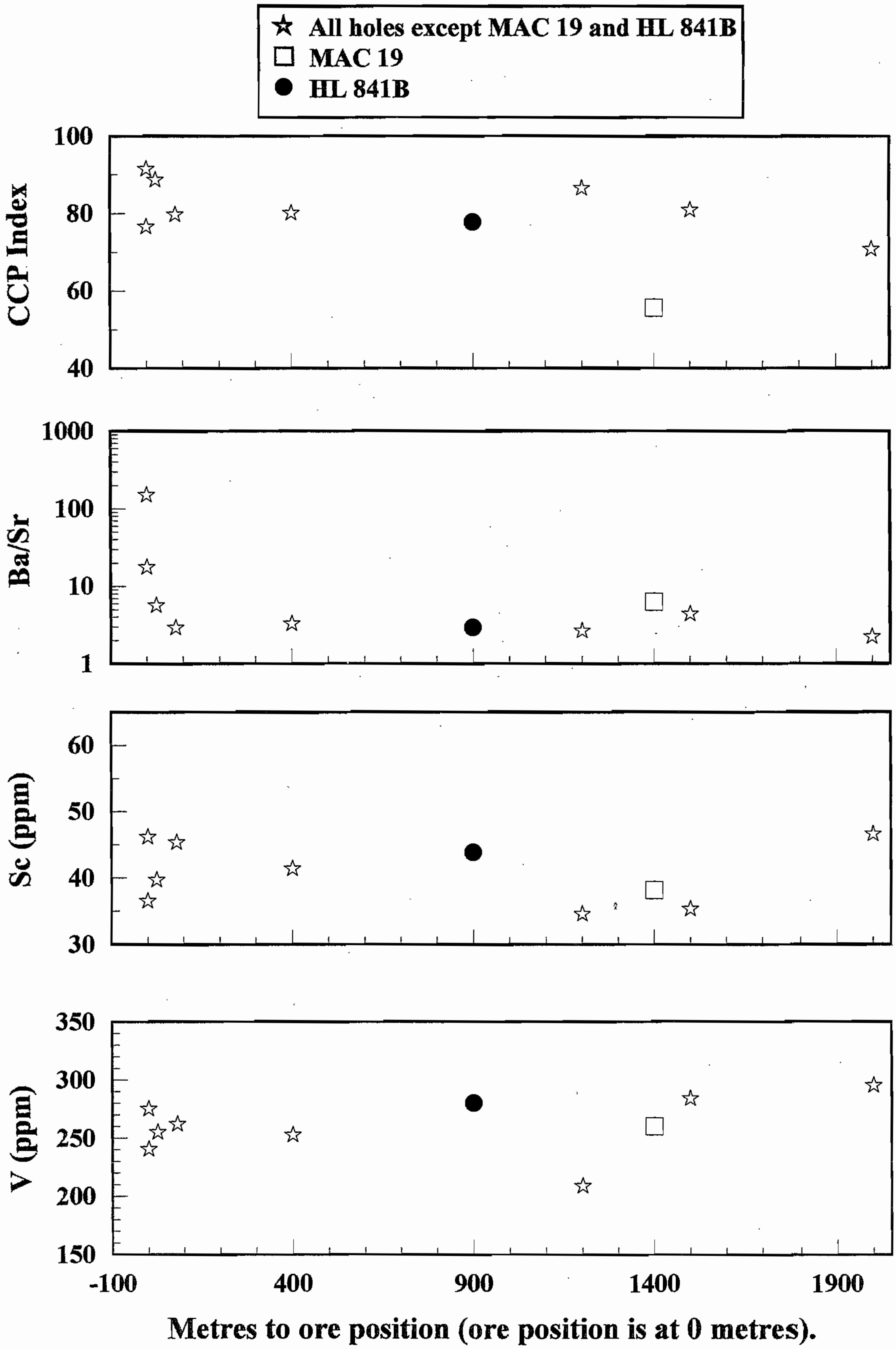


Figure 4.64e Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

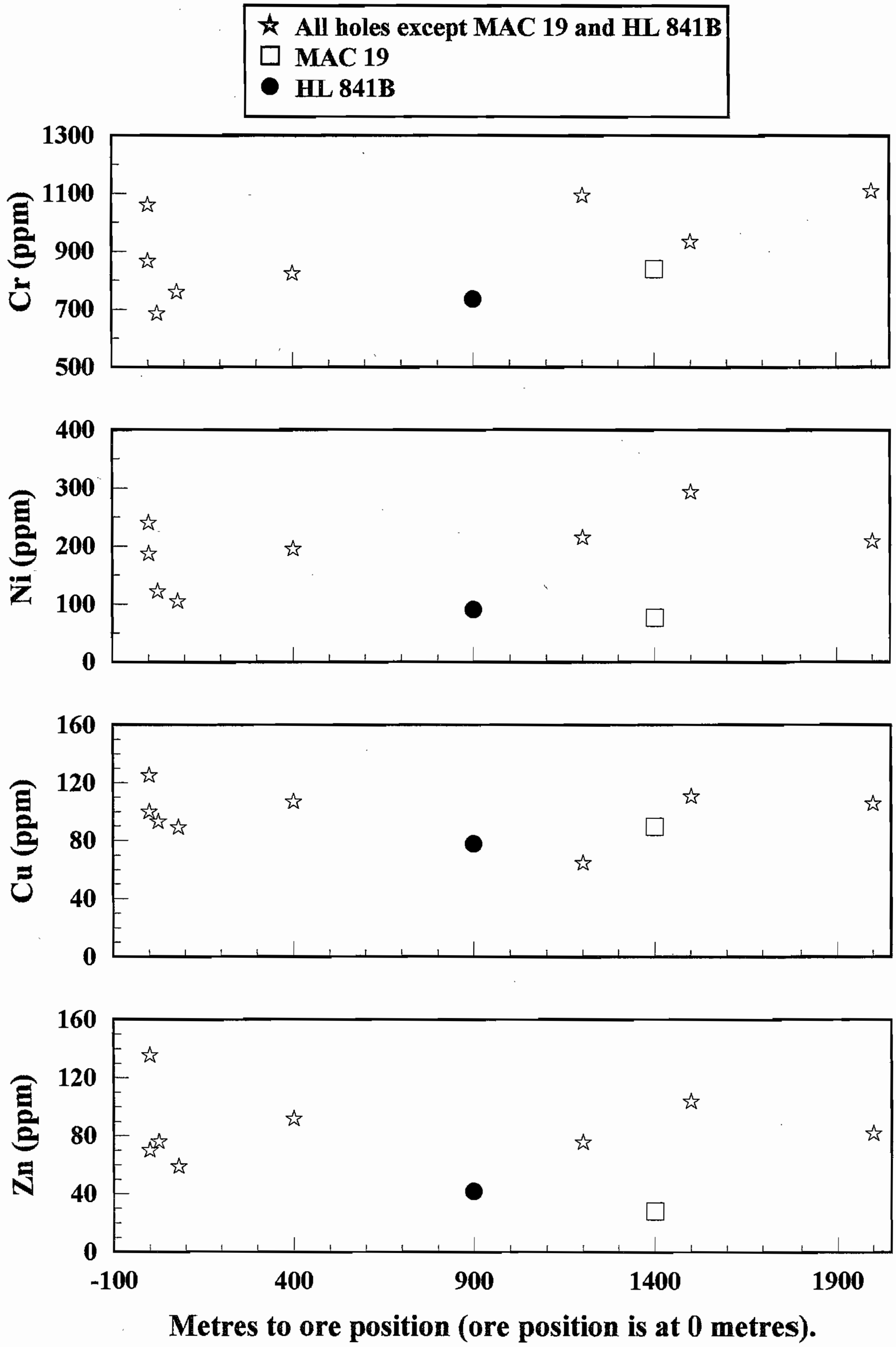


Figure 4.64f Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

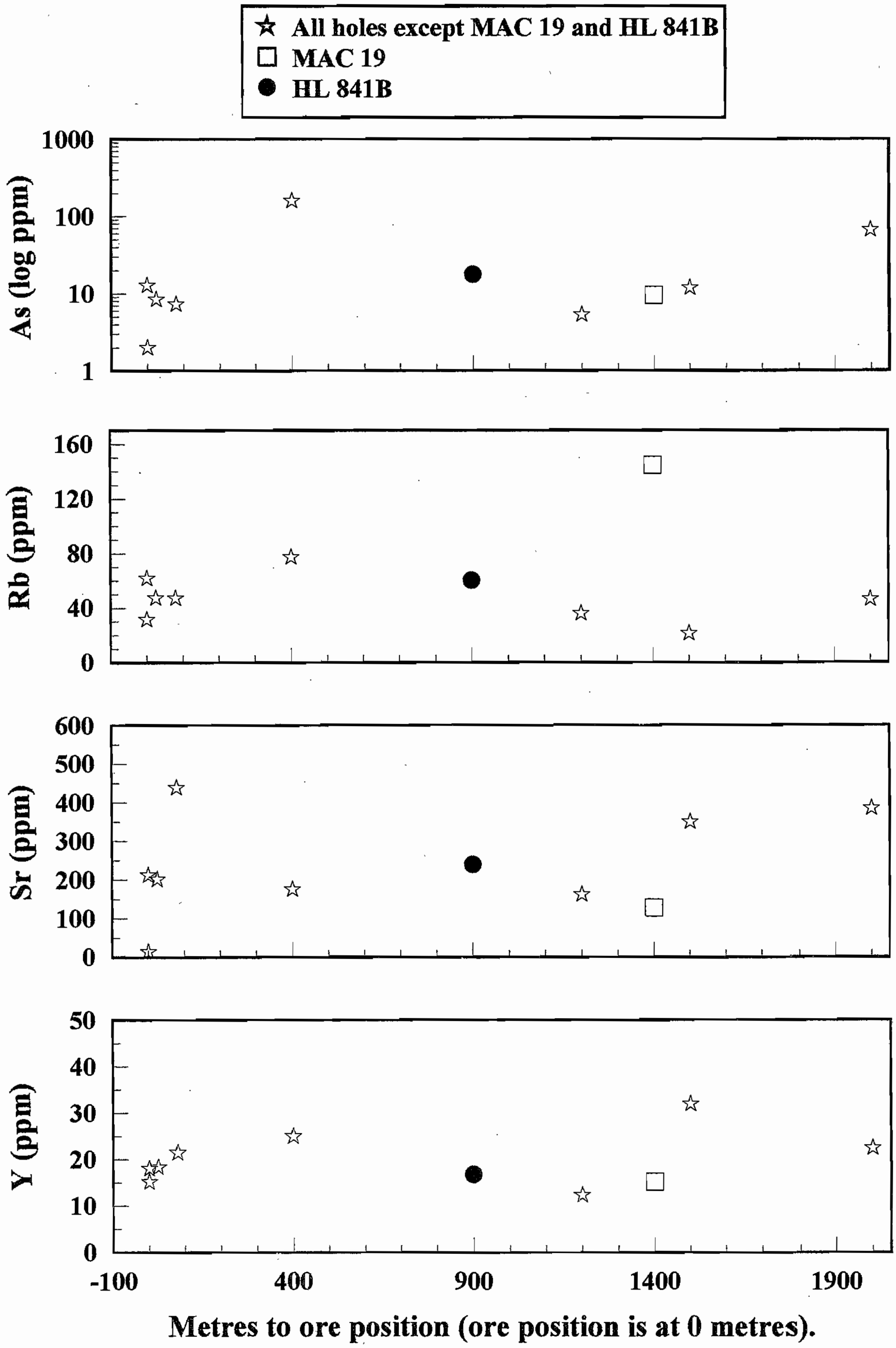


Figure 4.64g Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

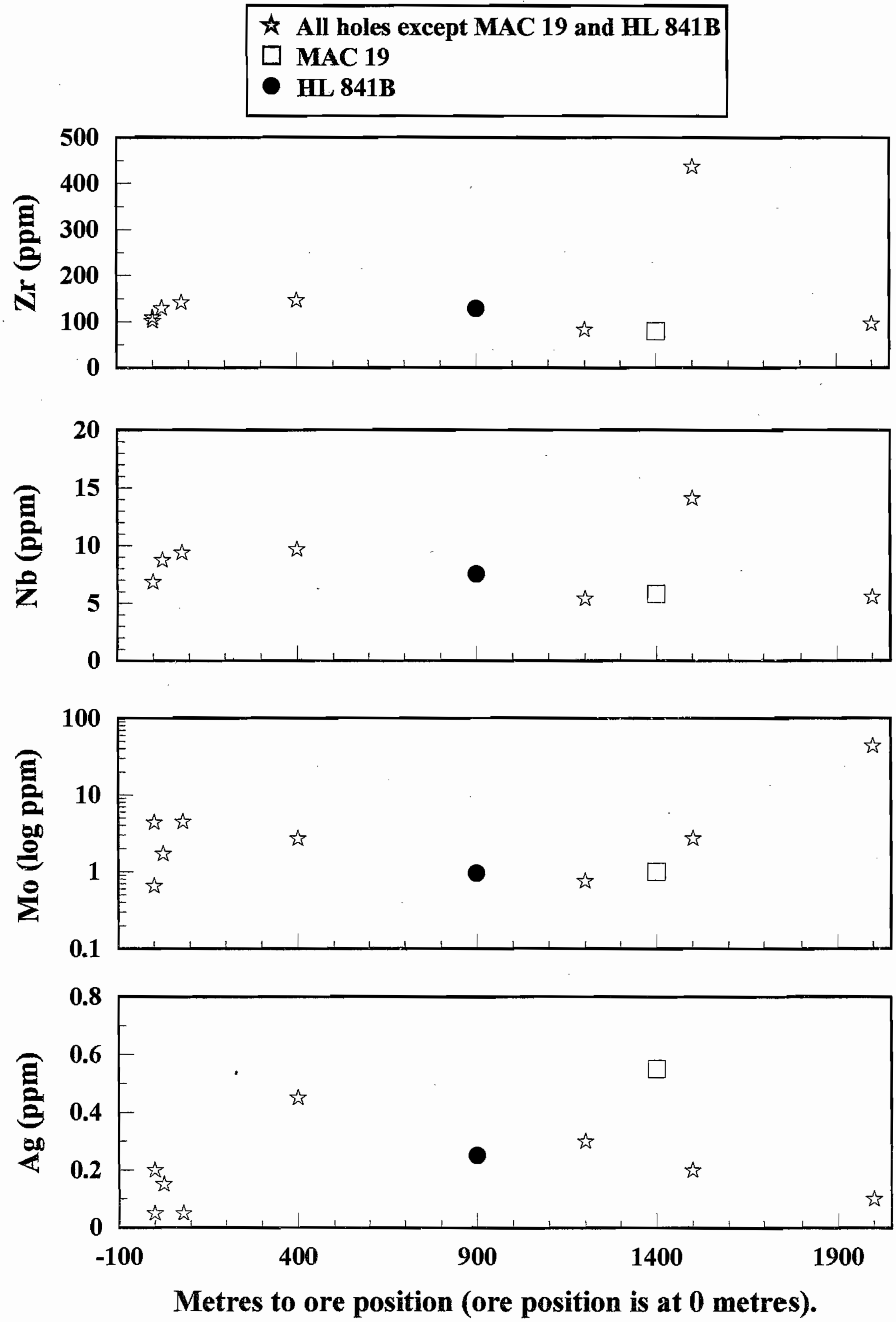


Figure 4.64h Hellyer basalt chemistry versus horizontal distance from centre of hanging wall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

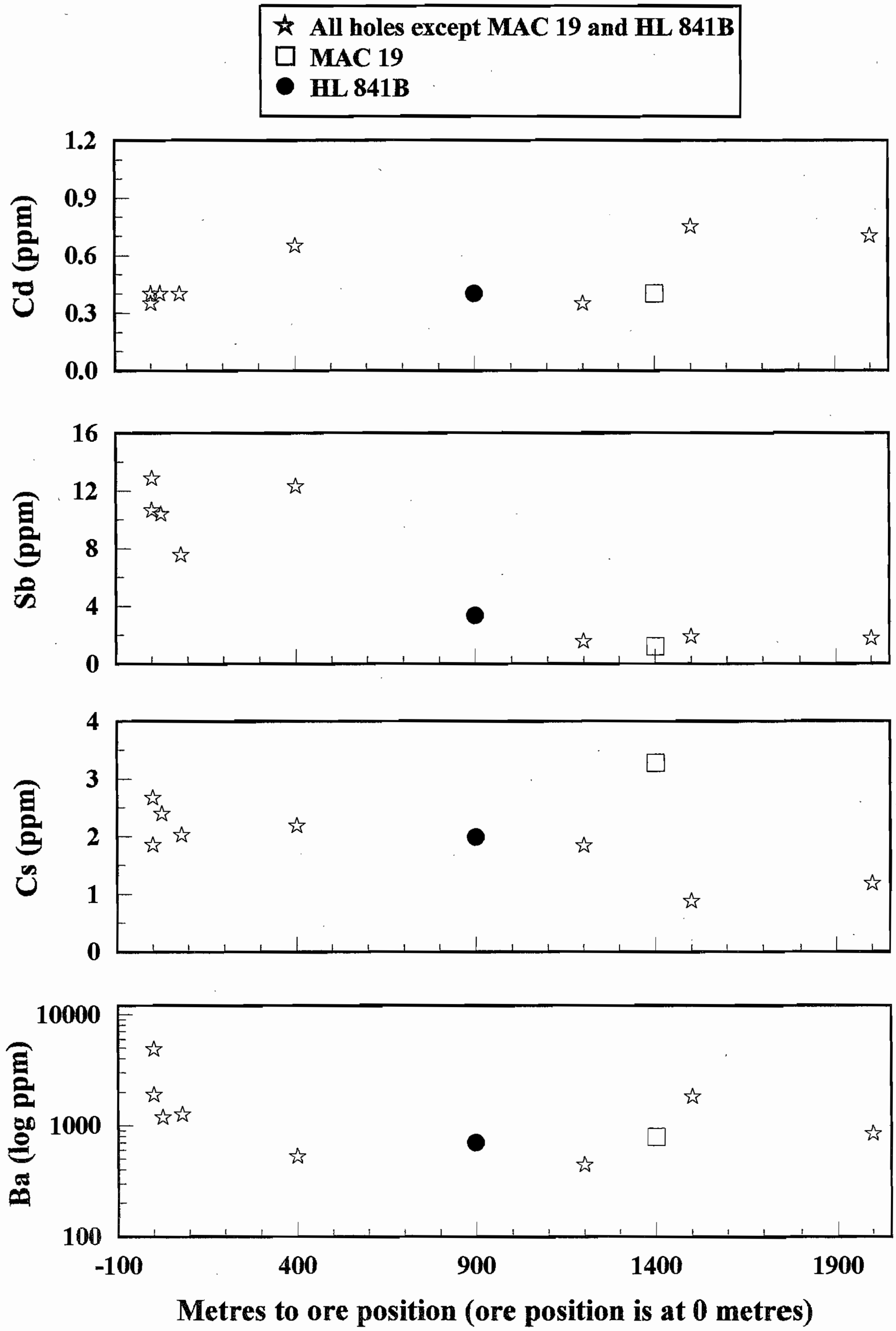


Figure 4.64i Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

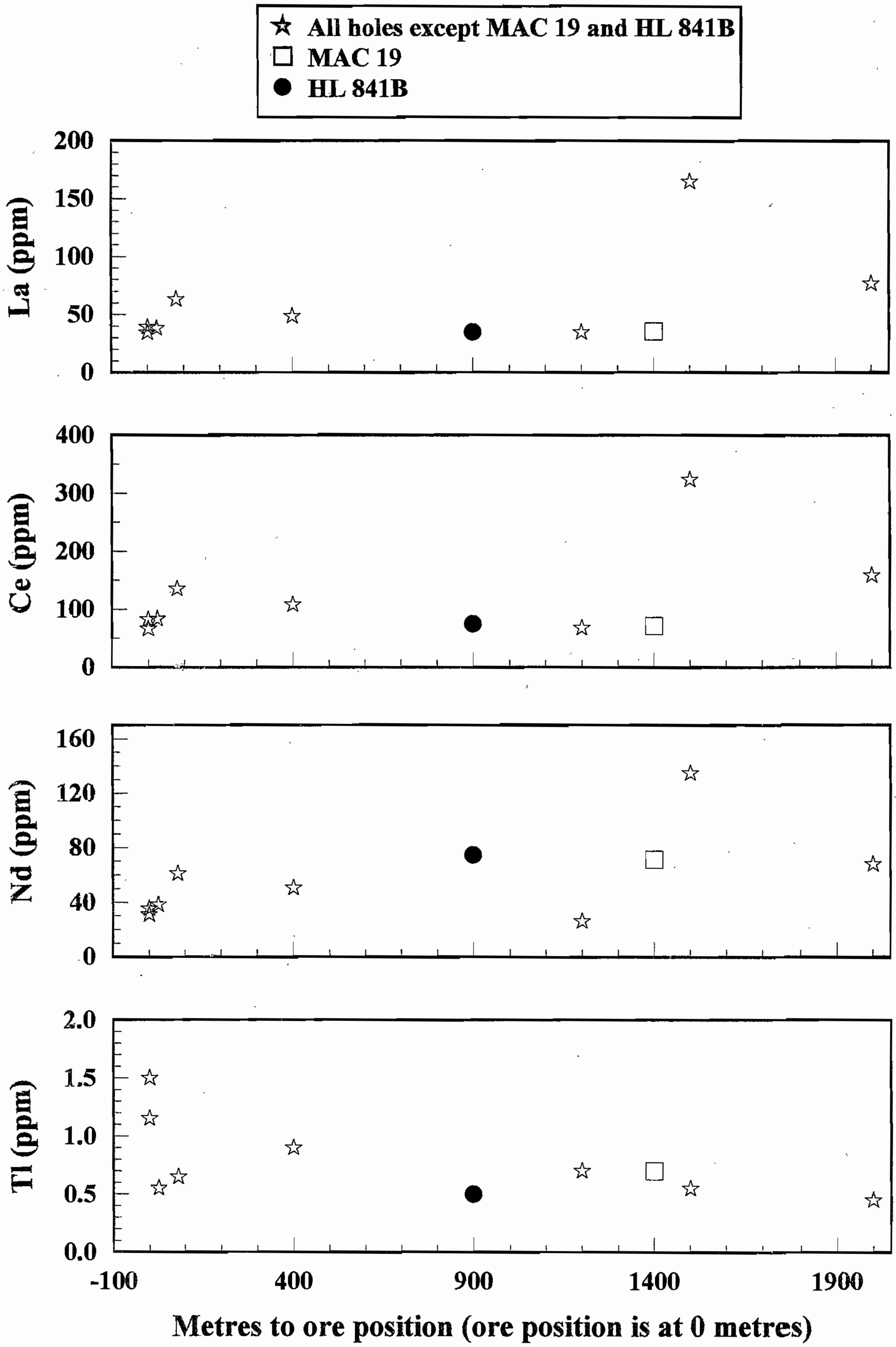


Figure 4.64j Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

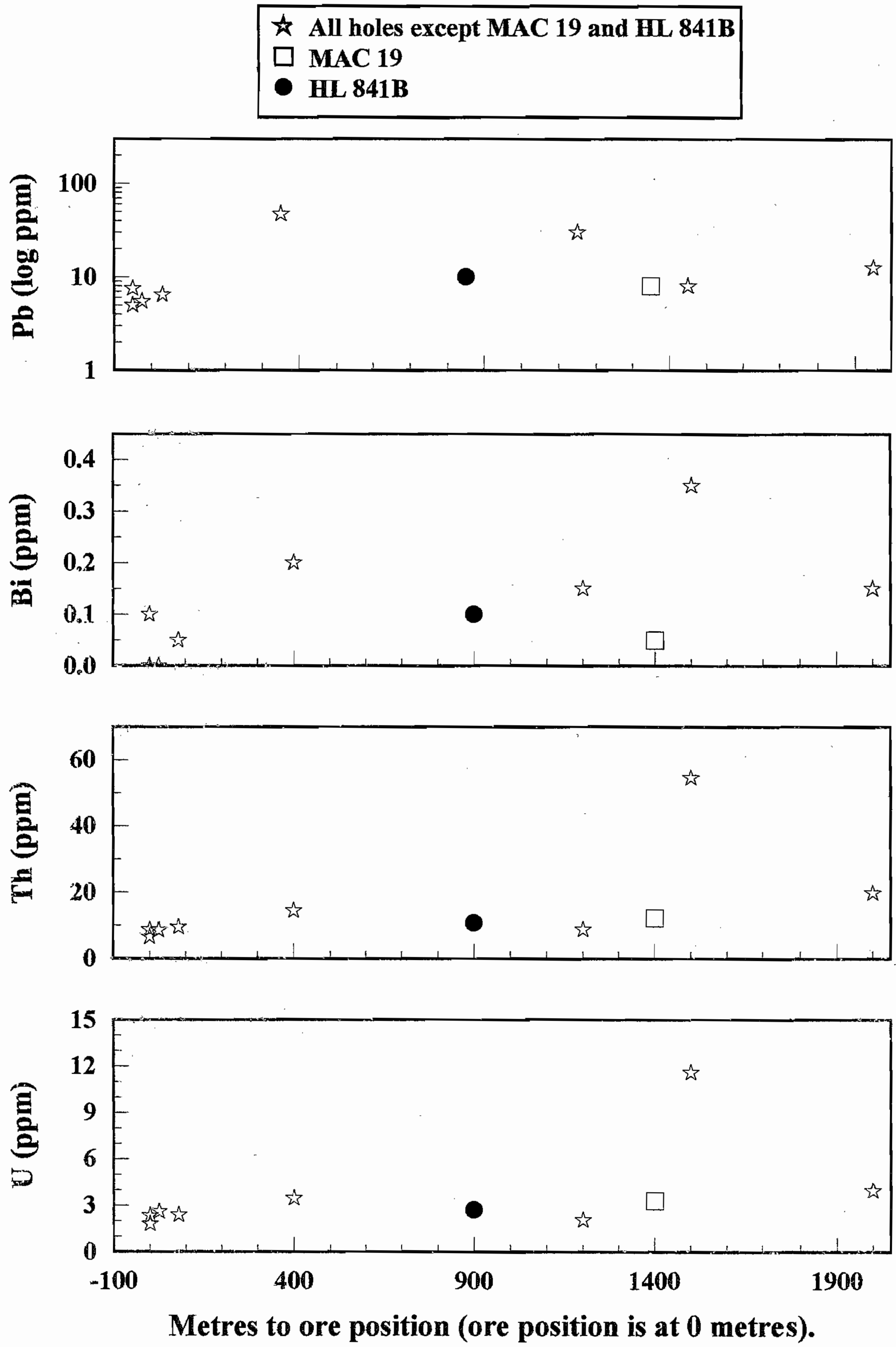


Figure 4.64k Hellyer basalt chemistry versus horizontal distance from centre of hangingwall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

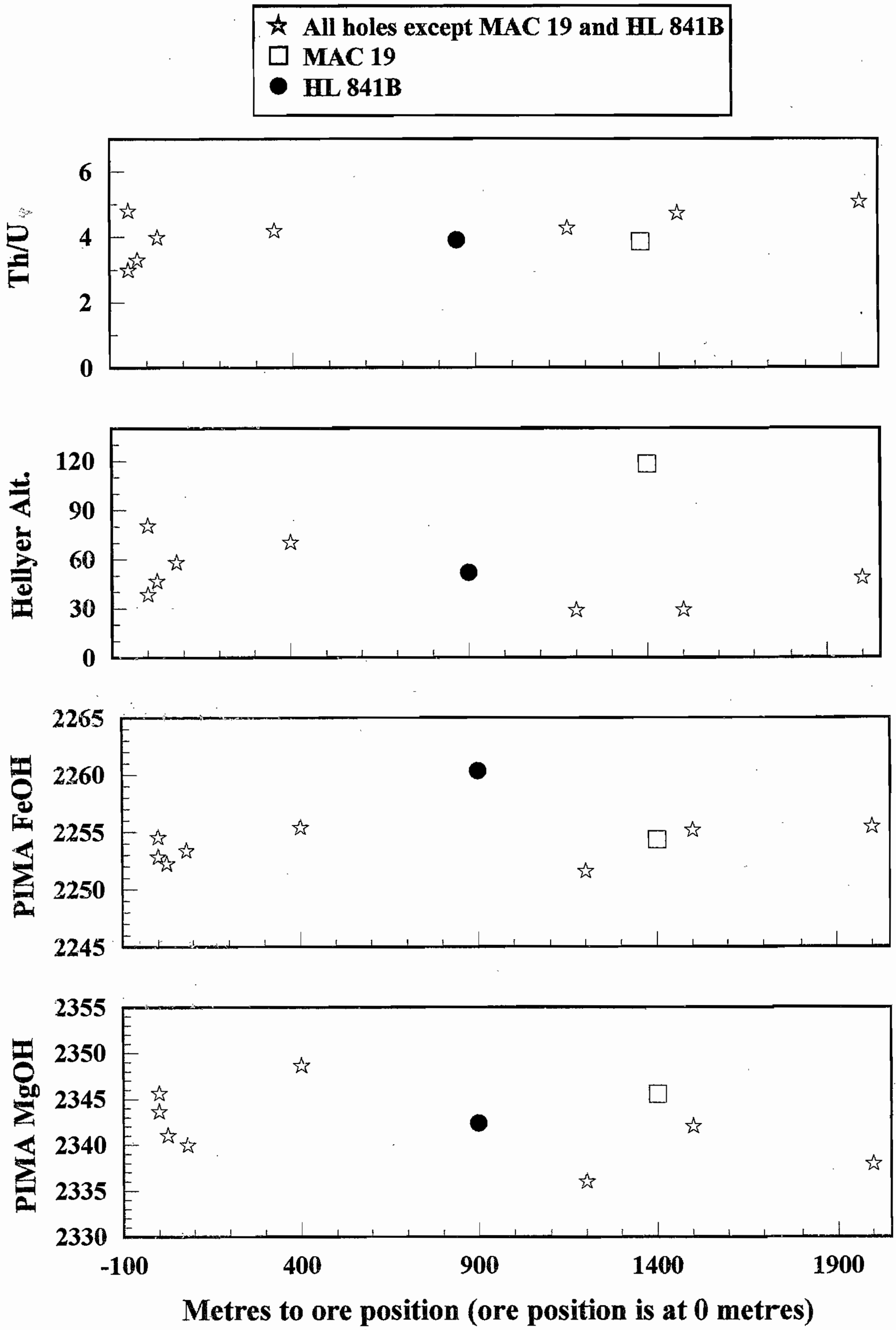


Figure 4.641 Hellyer basalt chemistry versus horizontal distance from centre of hanging wall alteration plume directly above ore body. Average of two samples taken from immediately below the Que River Shale. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

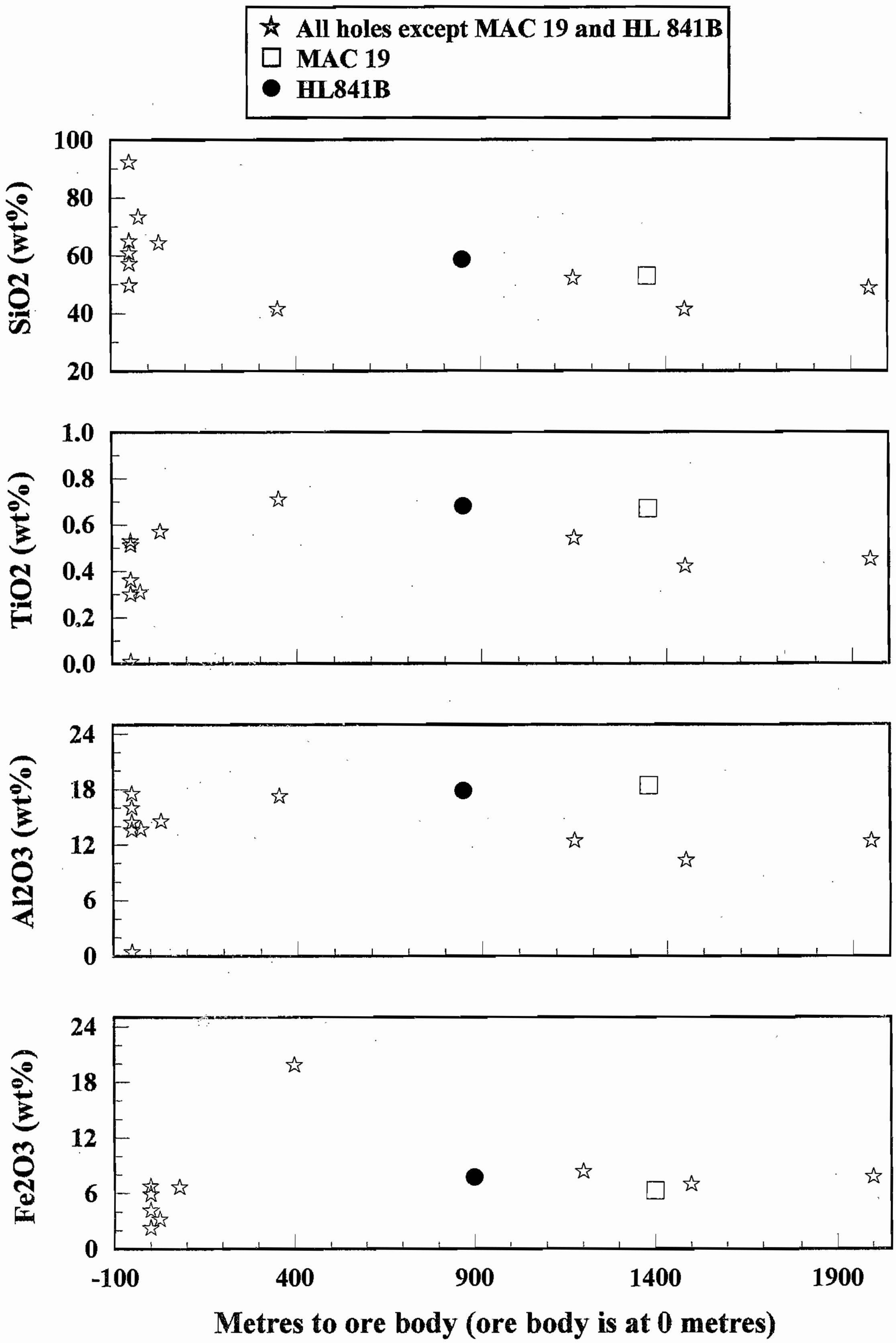


Figure 4.65a HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

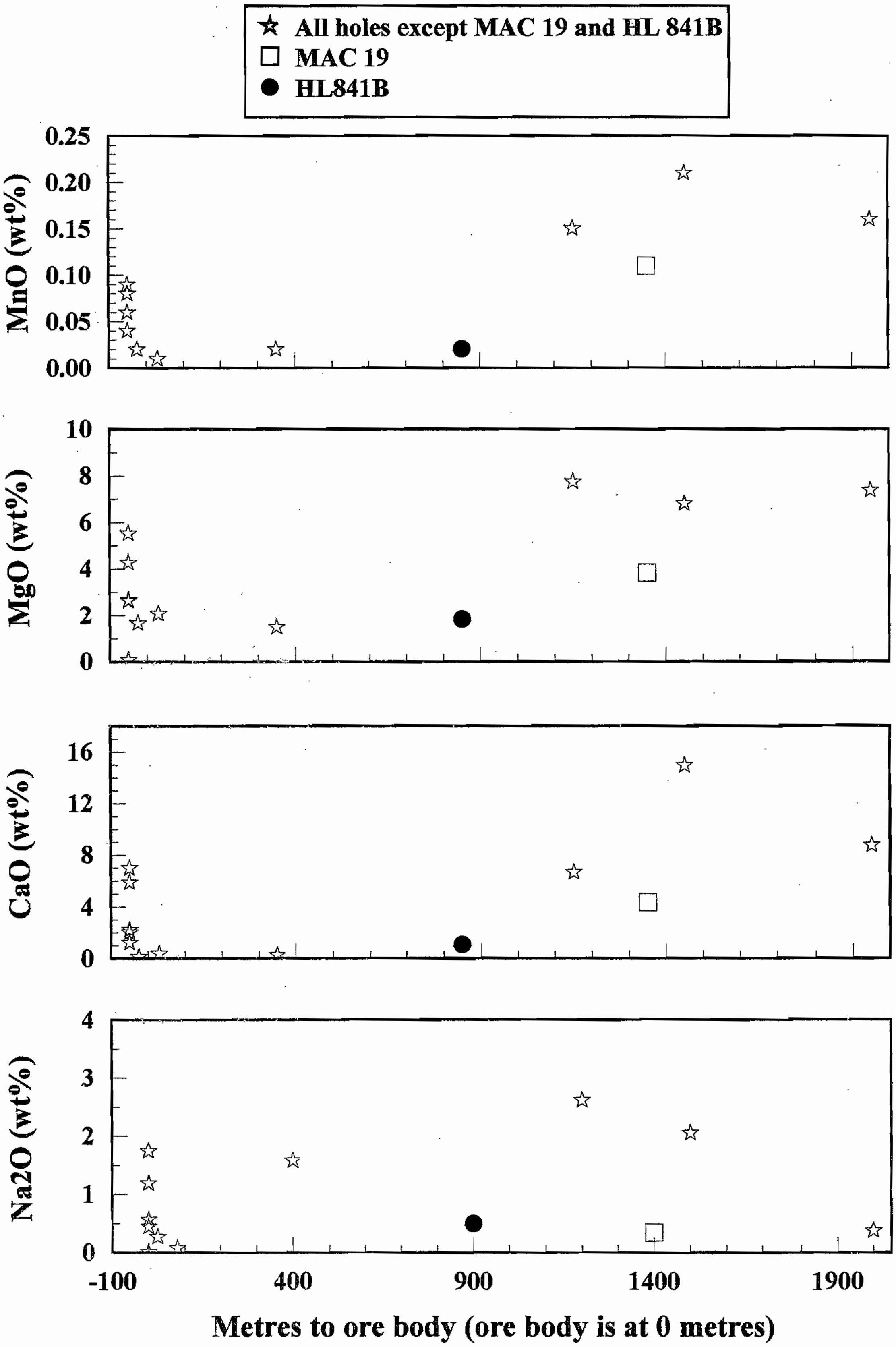


Figure 4.65b HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

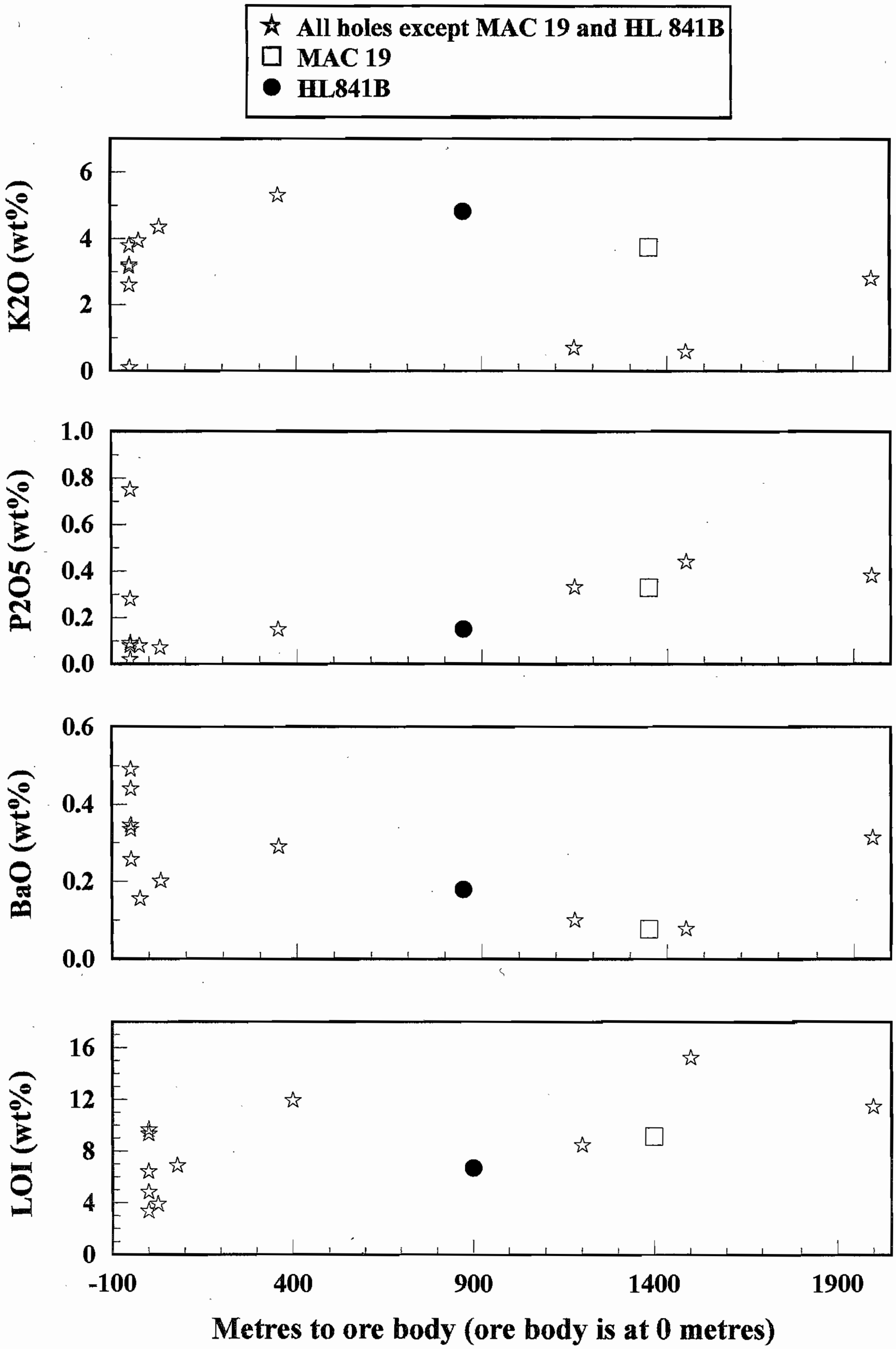


Figure 4.65c HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

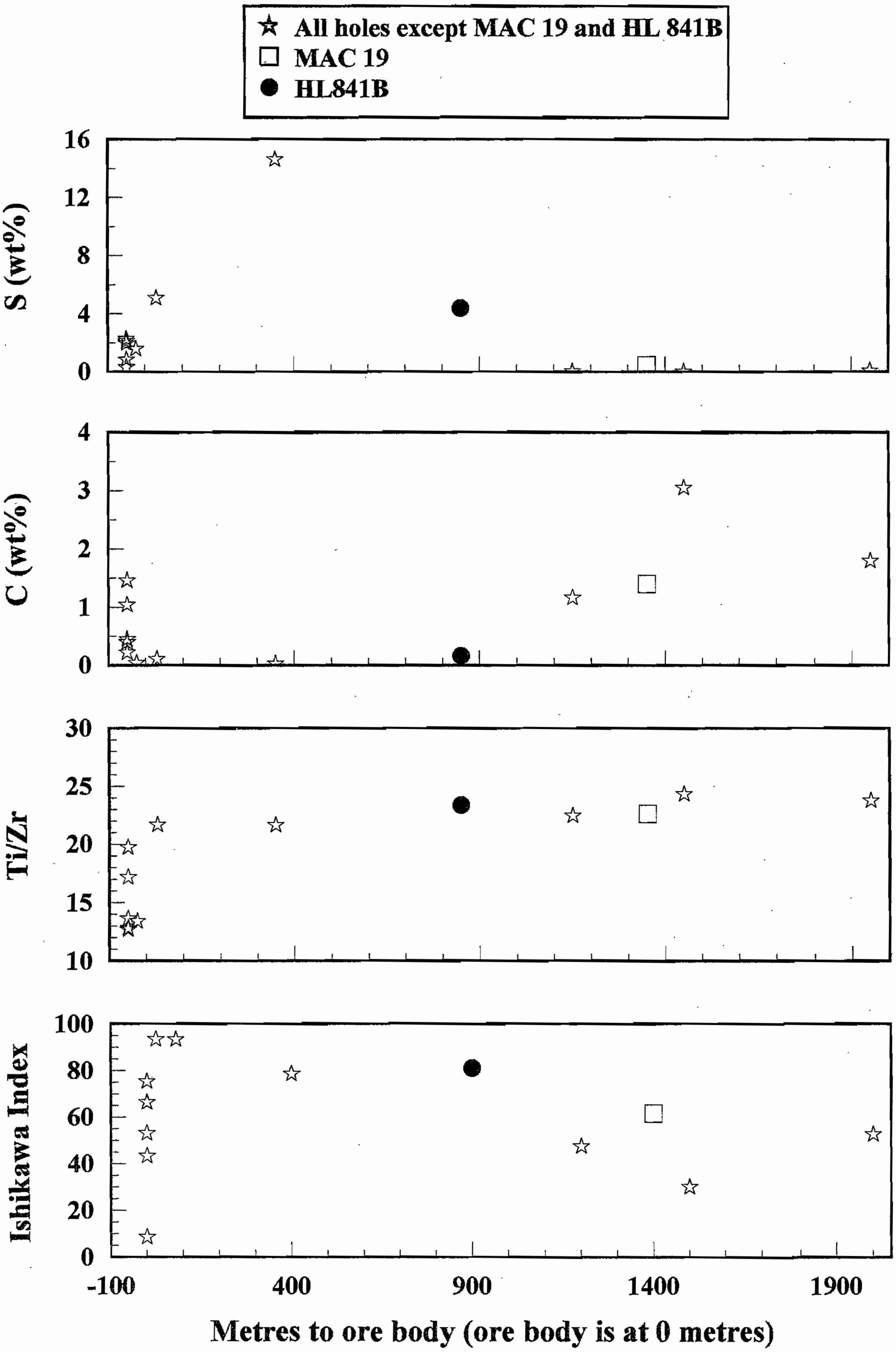


Figure 4.65d HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

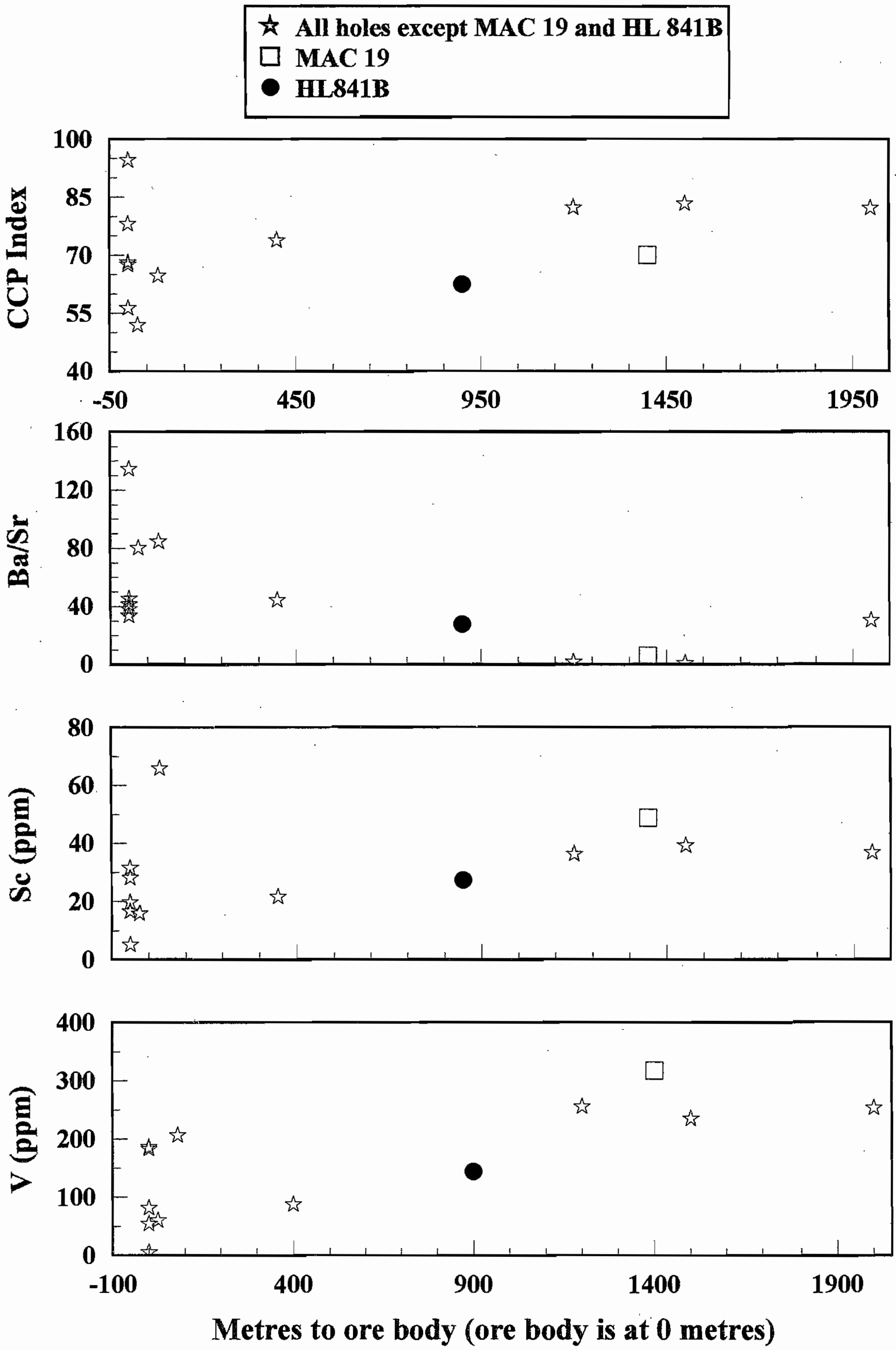


Figure 4.65e HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

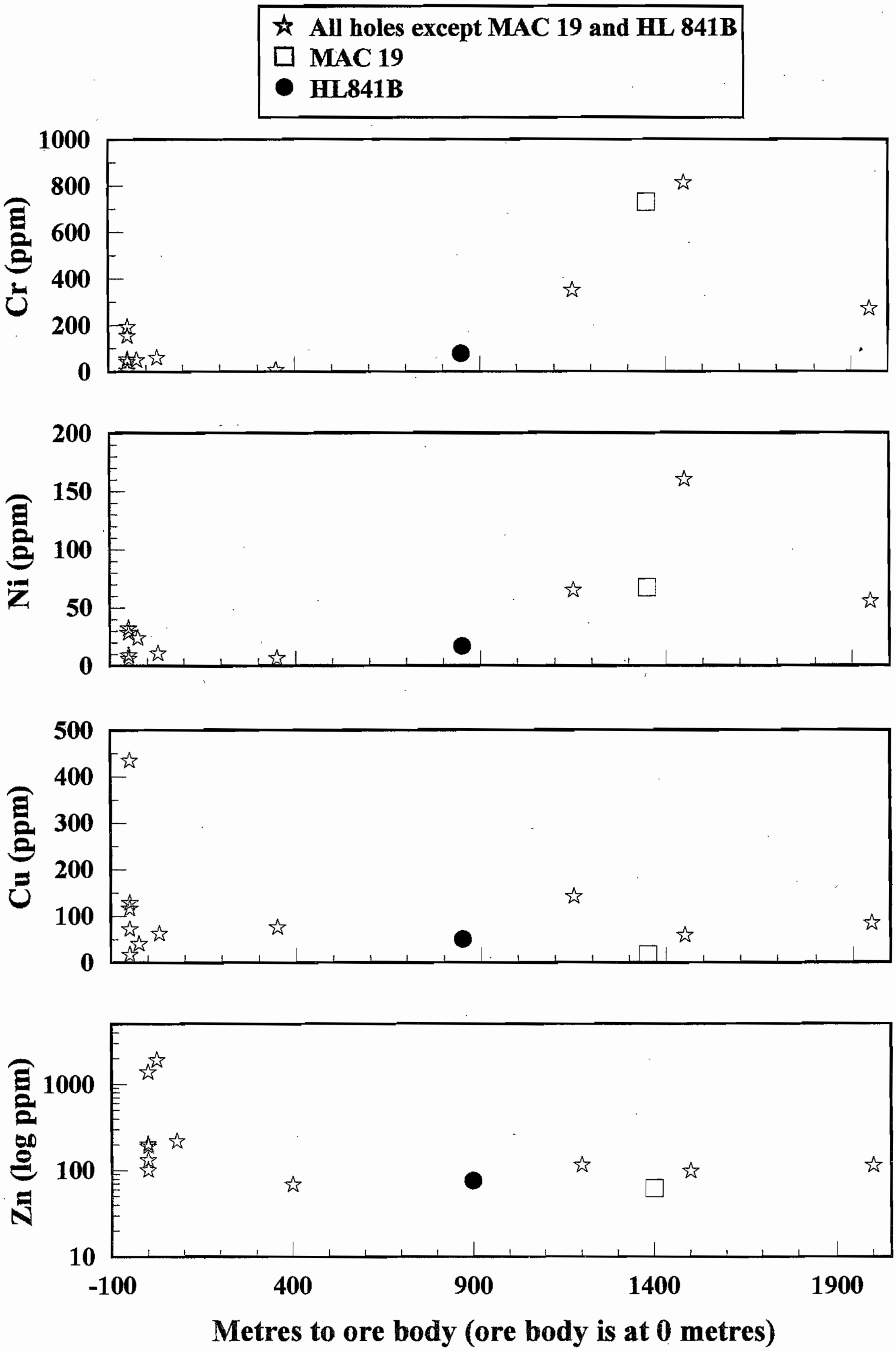


Figure 4.65f HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

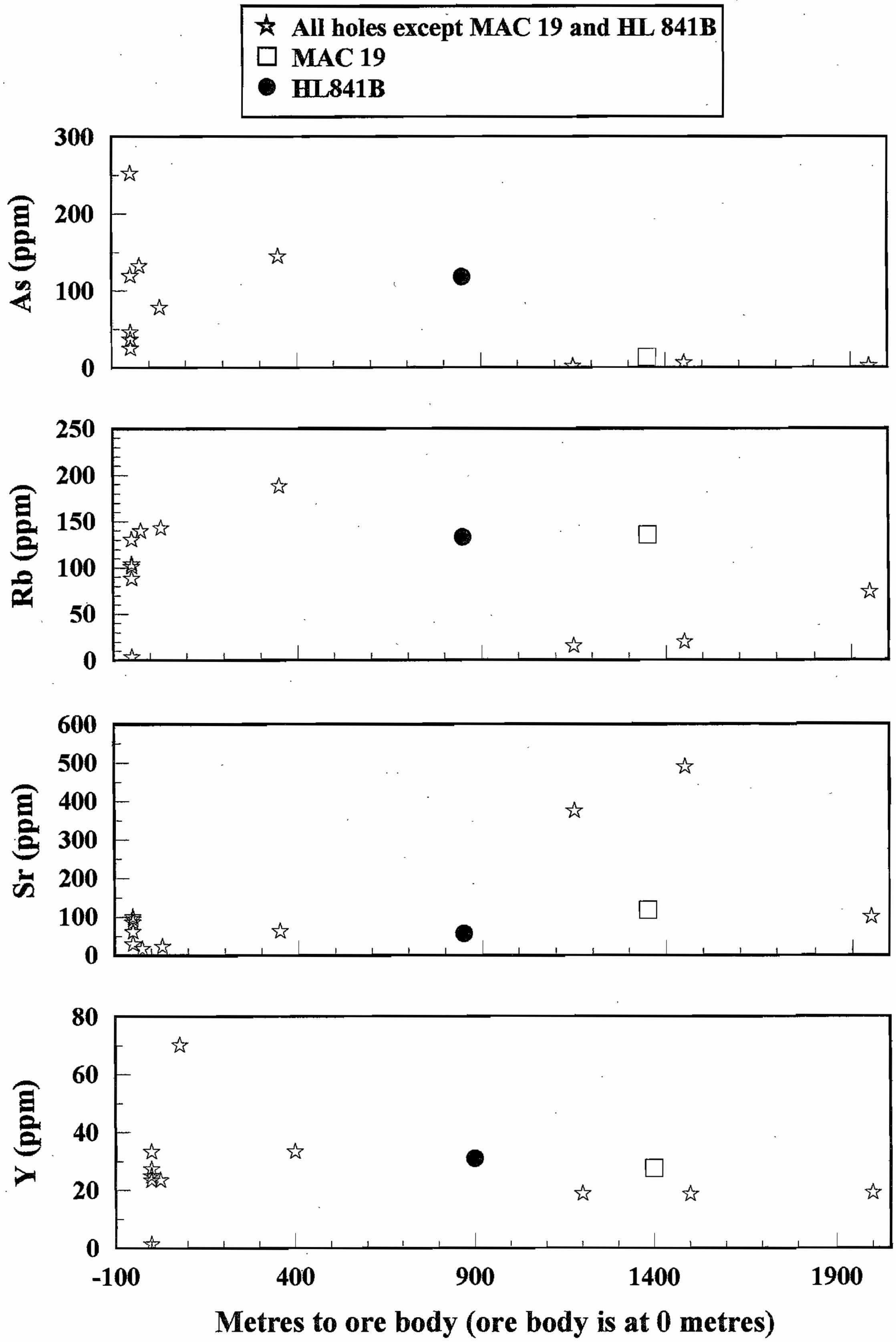


Figure 4.65g HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

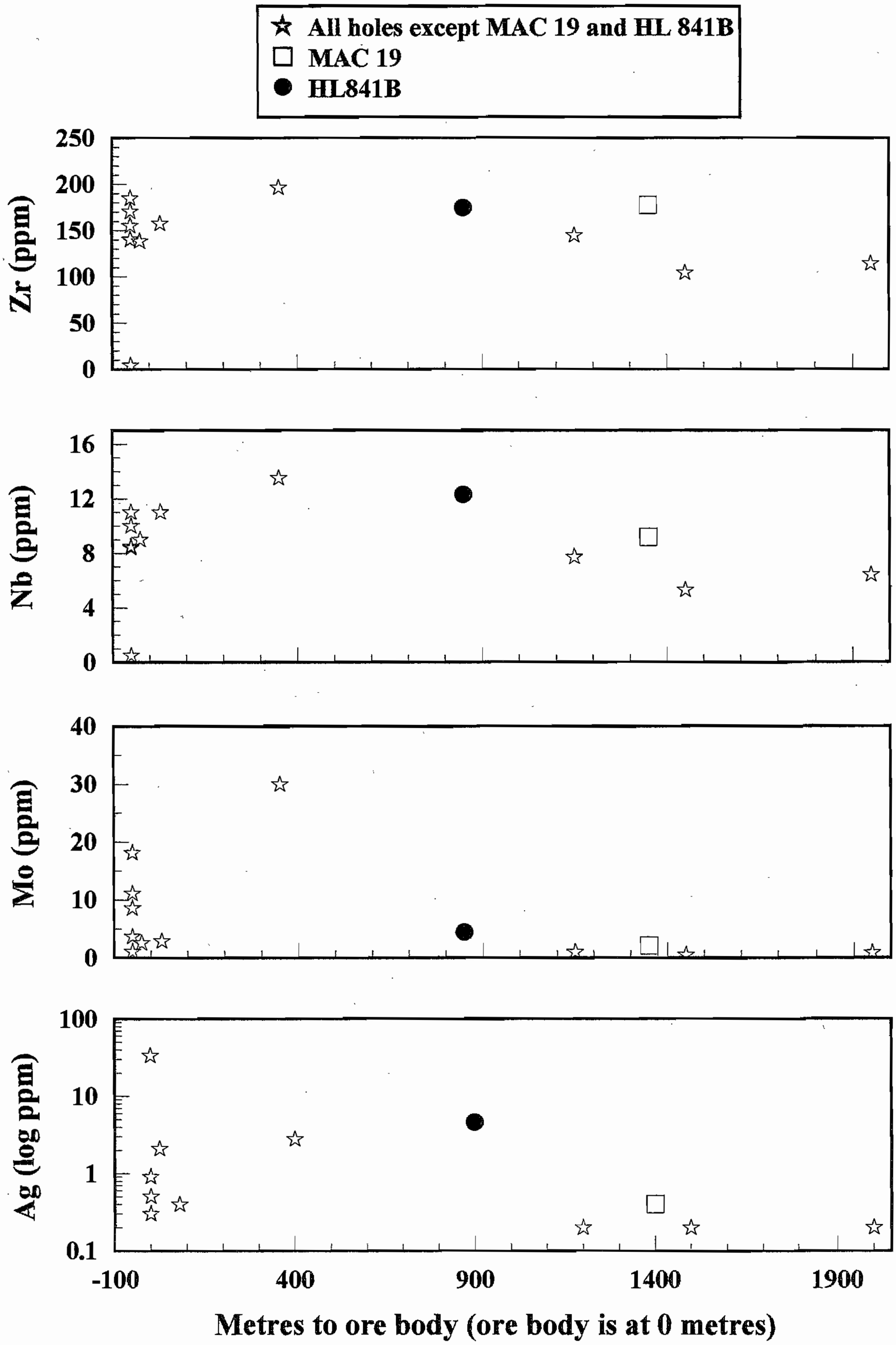


Figure 4.65h HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

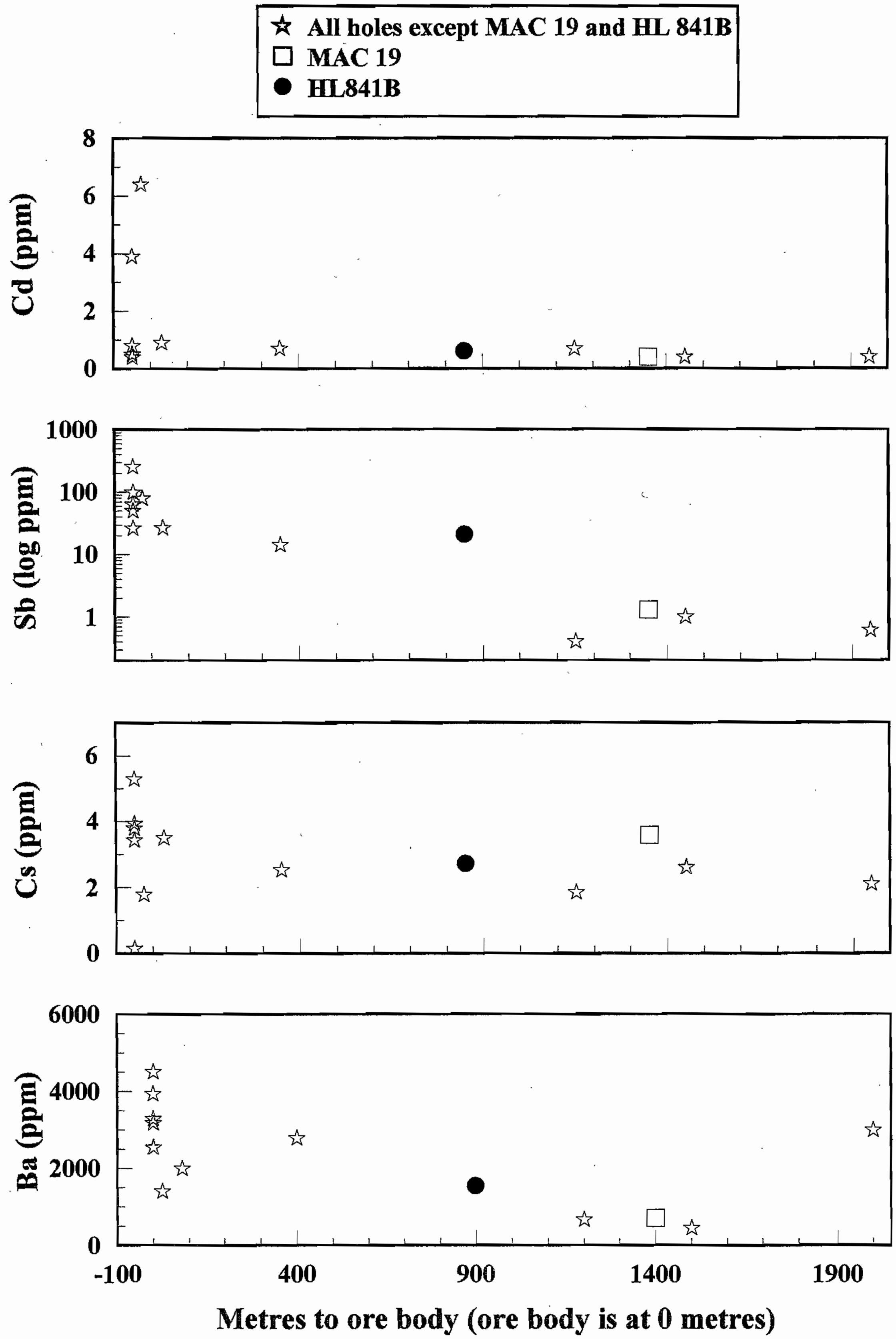


Figure 4.65i HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 84 1B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

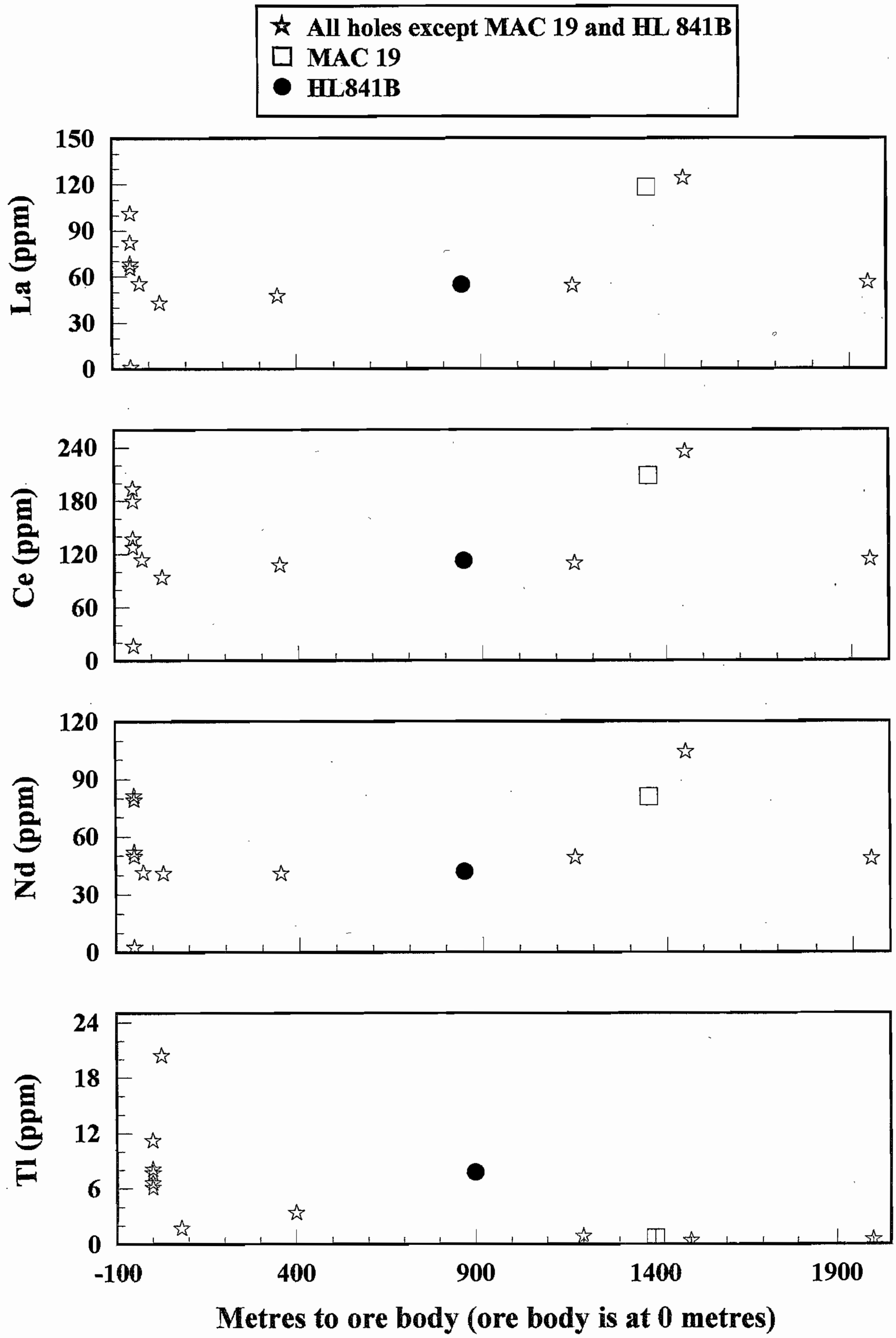


Figure 4.65j HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

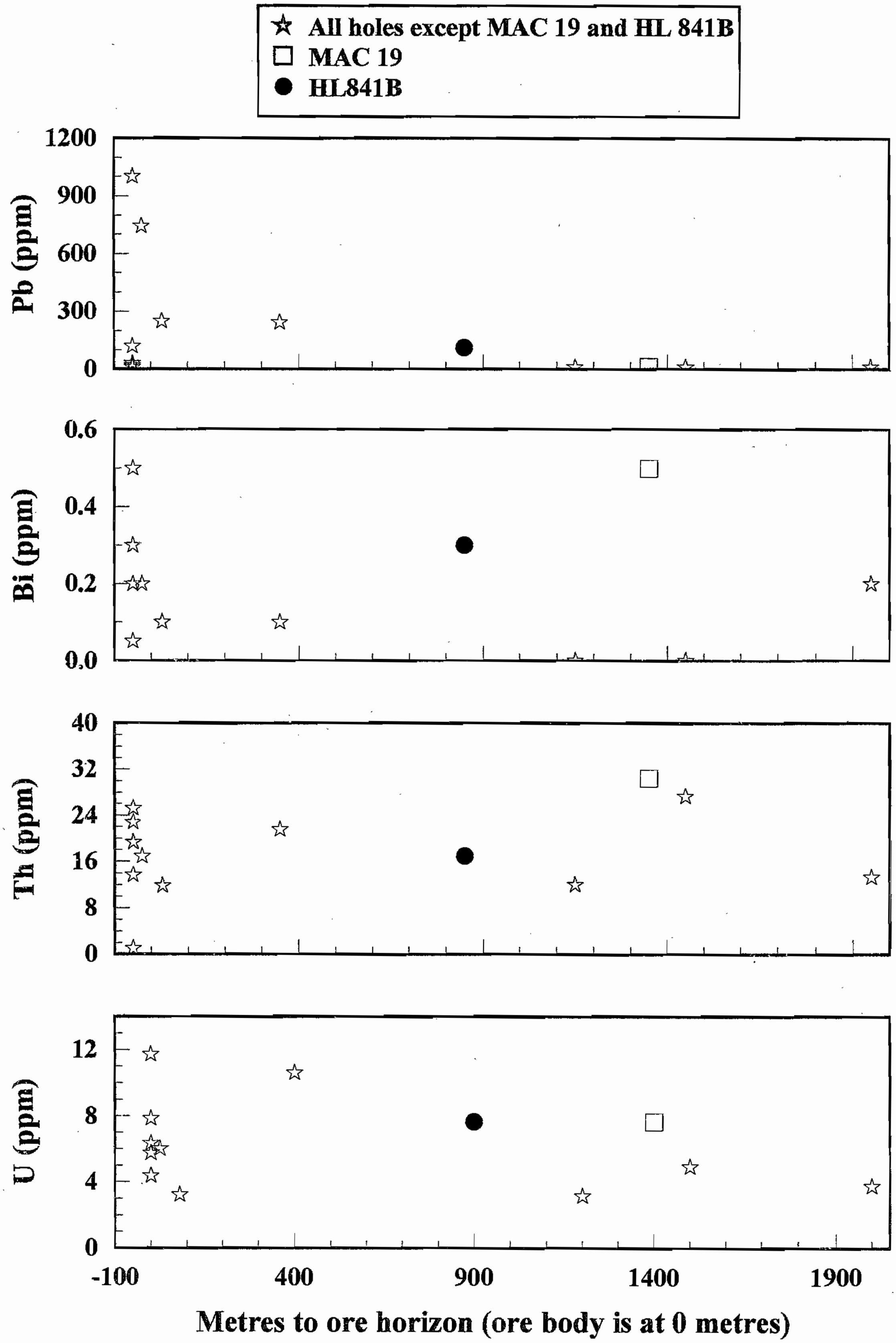


Figure 4.65k HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

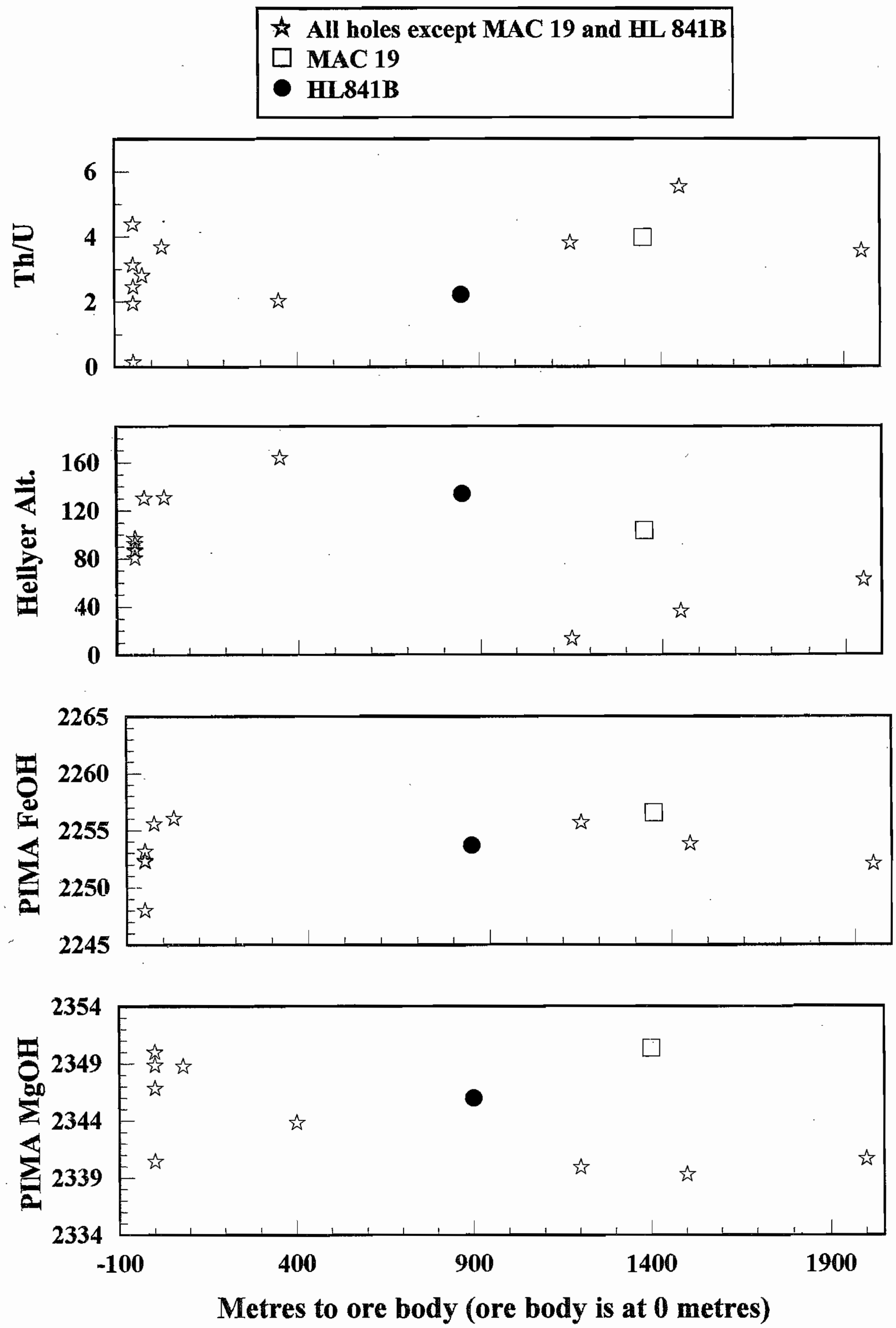


Figure 4.651 HVS chemistry versus horizontal distance from ore body. All samples are west of the ore body except MAC 19 which is 1400 metres east and HL 841B which lies 900 metres north-east but is collared within the surface projection of the north-east trending alteration zone which encloses the Hellyer deposit.

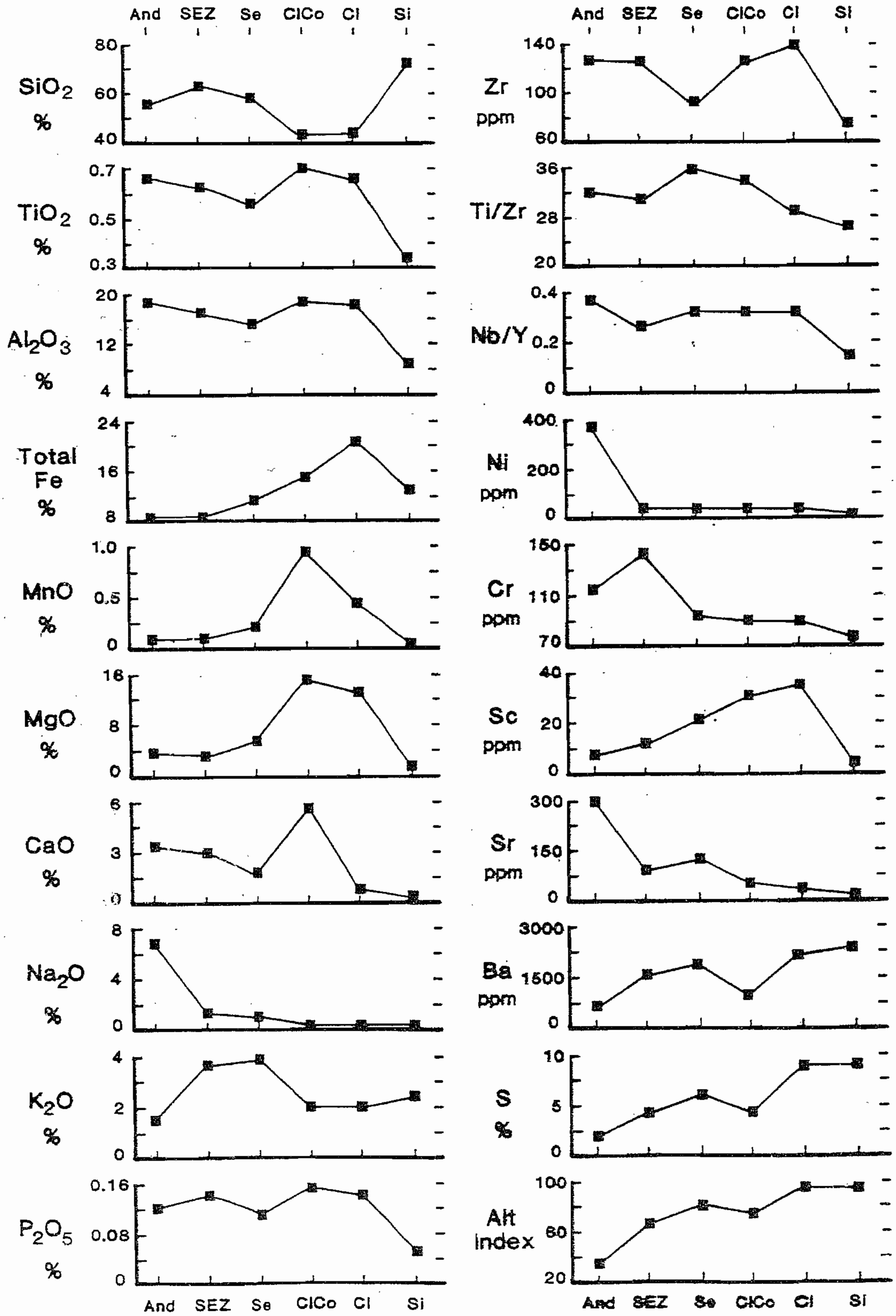


Figure 4.66 Distribution of major and trace element geochemistry between unaltered footwall andesite and various zones in the footwall alteration pipe. And = unaltered andesite, SEZ = stringer envelope zone, Si = siliceous core, Se = sericite, Cl = chlorite, Co = carbonate (primarily dolomite). From Gemmell and Large (1992).

Summary

Immobile elements within the Hellyer basalt are Zr, Ti, Y, Nb, La, Ce, Nd, Al, and Th.

A core lava above the deposit can be distinguished by higher Ti/Zr (40-45), Ni and Cr, and lower SiO_2, TiO_2, P_2O_5, Y, Zr, La, Nb, Ce, Nd, Th and U than the surrounding lava (Ti/Zr =20-25). There is some evidence for the core lava having lower Fe and PIMA MgOH wavelengths, while having higher Sb.

The Ishikawa Alteration Index is of limited use in the Hellyer basalt, an index has been developed based on deviation of CaO, MgO, Fe_2O_3, K_2O, and Na_2O contents from an an average unaltered basalt composition. Comparisons of alteration based on visual logging with geochemical parameters indicates that the visual logging can produce different alteration assemblages in similar rocks when the logging is carried out by different people.

C correlates positively with Ca, Mn and Sr and correlates negatively with Mg, indicating that there is little dolomite in the basalt.

Altered (proximal) holes can be distinguished from unaltered (distal) holes by depletion in SiO_2, Fe_2O_3 (except pyrite alteration), MgO, Na_2O, Sr, P_2O_5, Bi and by elevated values for CaO, K_2O, S, C, Rb, As, Sb, Cs, Tl. However, some of this variation must be due to the geochemical differences between the core lava at Hellyer and the surrounding lava, as discussed above. The top 10 to 20 metres of MAC 19 is also geochemically altered, being depleted in Fe_2O_3, MgO, Na_2O, P_2O_5, Sr and having elevated values of K_2O, S, C, As, Cs and Rb. HL 841 is also altered geochemically with depletion in Fe_2O_3, MgO, Na_2O, Sr, P_2O_5, Bi and elevated CaO, K_2O, S, C, As, Sb, Cs, Rb, Tl. HL

246, an unaltered hole 400 metres west of the deposit shows some signs of geochemical alteration, being elevated in CaO, S, As, Mo, Sb and Tl.

In terms of lateral variations in chemistry, Sb again shows substantial elevation above or adjacent to the deposit in the HVS, the basalt above the HVS, and the basalt below the Que River Shale. Ba, Ba/Sr and Tl are other parameters which show some pattern of increase, but not to the same extent as Sb. The strong elevation in Sb in HL 246 beneath the QRS horizon provides good evidence of the spreading alteration plume suggested by Jack, 1989.